A BRIEF HANDBOOK OF THE DISEASES OF CULTIVATED PLANTS IN OHIO

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BULLETIN

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A BRIEF HANDBOOK OF THE DISEASES OF CULTIVATED PLANTS IN OHIO

By A. D. SELBY

INTRODUCTION

The idea of disease is not a simple one, though it may seem so before trying to define it. In reality the term "disease" as applied to plants, means any change in that plant toward reduced vigor, etc., from the ordinary or average behavior. To put it another way, a plant is said to be "diseased" when it shows any deviation from the ordinary or average behavior of that plant in respect to appearance, growth, color of bark, foliage, fruitfulness, time of dropping leaves or length of life; in short, when the plant fails to conform to those averages which we have established by extended observation for the species and variety in question, we say it is diseased. Under such a general definition, variegated or purple hued sports would be included, although potentially rather than actually in diminished vigor. Variegated sports succumb easily to parasitic attack and, as later investigations show, are really suffering from enzymatic troubles.

The more usual symptoms of disease are marked by evident differences in the plant. The leaves become spotted, curled or discolored, or may even drop prematurely; the fruit may develop unevenly or be marked by decayed spots, or the twigs may blight, wilt or die. In all such cases we have a manifest loss of vigor and reduced profit. Yet we may not attribute all these to parasitic fungi or to parasitic insects; purely physical or chemical agencies may be at the bottom of certain troubles. Plants may be asphyxiated by too much water which excludes the air supply; they may likewise, be strangled by escaping gases, especially in the case of city shade trees, or their protoplasm may be attacked by chemi-

cal agents such as strong acids and alkalis. Quick growing plants appear to fall in drought, as with cucumbers when started during a period of excessive rains. Plants, and especially trees, may be locally injured by winter freezing, by hail, by overbearing with exhaustion of water supply, and by a variety of causes.

While we must keep our minds open to these varying causes of impaired vigor, by far the larger number of the diseases described in this bulletin are directly attributable to parasitic fungi which attack the plant or host in some vital part and rob it of its substance. The conditions of injury arising from the attacks of insects alone are not included. These fungus parasites of particular plants are of differing sorts, which produce, each, its more or less particular effects. It must follow, therefore, that the diseases produced differ in nature and that the names applied will vary accordingly. The names are not simply blight, rust, etc., indiscriminately applied—they are given with reference both to the parasite and its effect on the host plant.*

Parasitic fungi and bacteria which cause disease, being plants, though of lower class, have differences among themselves which may be clearly designated and defined. The names applied to them are accompanied by specific and generic descriptions which mark off the sort as definitely as do the descriptions on higher plants such as ferns, flowering plants and trees. The extreme minuteness of the parts of parasitic fungi and bacteria make necessary the use of the microscope in their description and detection. The parts called spores which reproduce these minute plants have special form, size, etc., by which these are recognized when found.

The agencies for the spread of parasitic diseases are those operations in which we engage or those which surround and envelop the plants as well as ourselves. Light spores will be carried by currents of air like particles of dust. All spores or germs of these lower plants may be carried by numerous agencies such as insects, higher animals, and man. They will also find entrance into plants by whatever openings exist at the time. The epidermis of a green leaf or stem has breathing pores or stomates in it; the leaves of mustard plants have water pores in them and wounded plants have these fresh openings to invite the entrance of the disease conveying spores or germs.

The remedies for plant diseases are based upon the character and life history of the particular parasitic growth with which we have to deal and upon the nature of the host plant itself—some hosts being very different from others in respect to permitting of sprays of fungicides or insecticides. Common sense inferences are

* See naming of diseases.

always of use in dealing with plant diseases. If the soil is too wet, drain it; if late growth predisposes to winter injury, avoid such growth; if overbearing weakens plants, prevent it by thinning the fruit.

The philosophy of seed treatments is stated under diseases which infest the seed; that of soil treatments or disinfection, under soil infesting disease, and the general doctrines of sprays, fungicides, etc., under that heading further on. The progress made in plant disease prevention throughout the world during the period of about 26 years which has elapsed since the discovery of Bordeaux mixture in France shows how well adapted that discovery was to the needs of the times.

The progress made in recent years in the study and control of plant diseases has been made possible by the agencies recently developed in the United States in the Agricultural Colleges, the Agricultural Experiment Stations and the United States Department of Agriculture. It is not expected that this advance in our knowledge of the diseases of plants or of the methods of disease control will soon wane. Efforts like the present one to present briefly the doctrines of disease and the philosophy of disease control together with brief descriptions of prevailing diseases in our state, have for their purpose the wider dissemination of the body of present day knowledge in these lines. Such a statement will not close the march of progress nor make less the need for more knowledge. It is hoped that cultivators of plants, whether farmers, gardeners, horticulturists or florists will find suggestive statements of information in the bulletin by which they can direct their own efforts to better advantage and correct or broaden their own inferences from observed conditions about them. All such results will not only increase the need for more knowledge, but will furnish impetus to the movements by which we will gain the desired information.

In the preparation of the revised edition of the original Bulletin, No. 121, the general part immediately following this introduction has been considerably enlarged and brief discussions are now given concerning groups of plant diseases as well as those concerning parasitic fungi. It is fully apprehended that the host plant is the center of practical as well as economic interest and these statements concerning enzymatic diseases as in the case of peach yellows and mosaic disease of tobacco, diseases transmitted in the seed, soil infesting diseases, and the relation of the spread of certain diseases to leaf biting insects are given as aids in mastering the principles involved. The same aim has governed the discussions upon wounds

and wound fungi so especially dangerous with orchard, shade and forest trees. Somewhat fuller discussion of atmospheric agencies as affecting the occurrence and spread of plant diseases, of remedies for diseased conditions and of the application of the latter in combatting diseases and a presentation of storage troubles has also seemed desirable. Special attention is called to the host plant in the matter of breeding or selection for disease resistance and in the contrasts offered by American and European points of view in plant disease study.

ACKNOWLEDGMENTS

The illustrations in this bulletin have been drawn from wider sources than in the previous hand book. A large number, including perhaps, a larger portion of the cuts, are taken from previous publications of this Station by Weed, Miss Detmers, and the writer; small cuts have been at times made from certain larger illustrations while with others only portions of the original cut have been used.

A great many of the illustrations are new, and I am deeply indebted to Messrs. J. M. Van Hook and Thos. F. Manns for many of the photographs from which these have been made. I am also indebted to Professors Halsted of New Brunswick, N. J., and Atkinson of Ithaca, N. Y., and to the Bureau of Plant Industry of the U.S. Department of Agriculture for many favors in the matter of cuts which are used in the Bulletin. Figures 24, 25, and 26 are from Dr. Freeman's "Minnesota Plant Diseases." For permission to reproduce these, I am indebted to Prof. Frederick E. Clements, of the University of Minnesota. In all cases where it is not otherwise obvious, it has been the aim to state the source of the illustrations in the descriptions. The same applies to illustrations reproduced from standard works.

In many matters connected with recent investigations of the Department bearing upon diseases included in this present bulletin, and upon current examinations, I am under many obligations to Thos. F. Manns, Assistant Botanist, who has rendered very great assistance.

GENERAL PART I

CONCERNING PLANT DISEASES IN GENERAL

As defined in the introduction, a plant is called diseased when it fails to show normal vigor and normal condition of its parts. The manner of disease attack is extremely varied and the conditions set up as a result of disease are accordingly of many different kinds. We learn to recognize disease by the symptoms shown in the plant; these symptoms will at times be readily interpreted and on other occasions they will prove misleading. Nothing is plainer than the necessity for continuous observation of growing plants if one is to be in a position to interpret the symptoms of disease.

Fig. 1. Roots of white burley tobacco plant attacked by broom-rape. Each of these masses attached to the root shows beginning of the plant which will grow up in larger dense form, and produce an abundance of blossoms and seeds but no leaves. Each one of these must have started from a buried seed of the broom-rape, *Orobanche Ludoviciana* Nutt.

Diseased conditions may be due to the very obvious attacks of certain parasitic seed plants which lack leaf-green or chlorophyll in their tissues and must subsist on other plants somewhat after the manner of parasitic fungi. The dodders which attack the clovers, alfalfa, onions, etc., belong in the class of parasitic seed plants of the genus *Cuscuta*. Their seeds are liable to be harvested with the

seeds of clover or alfalfa and to be present in the commercial seeds. While these have been treated in the weed manual they require mention here. The seedling plant of dodder first forms a root and sends upward a whitish stem which twines about the clover or other stem, and sends sucking branches into the stem interior. These "haustoria" extract food material from the clover stem—that is they rob it of its own substance. Upon the formation of such organs the root of the dodder dies off and the future existence of these twining, strawlike stems is at the expense of the host plant.

A similar state of parasitic existence is found in the broomrape tribe whose very small seeds are scattered through the soil. Such a broomrape is well known on hemp, and the same hemp broomrape also attacks tobacco in Kentucky and possibly in our state. We have found another broomrape attacking tobacco in one district of Brown county, Ohio, and the illustration shows its appearance on the tobacco roots.

When the leaves of a plant are attacked these show the direct effects; the symptoms of parasitic leaf diseases are usually localized injury resulting in spotting and often in browning of the leaf parts. Leaves may dry up somewhat slowly and drop to the earth, and yet the leaf tissues are simply dried up. Such conditions may result from late frost as upon shade, fruit, or ornamental trees. A most interesting case was once studied upon catalpa as a result of a frost in May. In that case the drying up was none the less to be expected at that time.

An even more interesting case of leaf drying and dropping was upon young catalpa trees in a nursery caused by the attacks of a root-rot fungus, *Thielavia*. Owing to the death of many of the rootlets and finer roots as a result of the root-rot trouble, the leaves of these young trees dried up prematurely in August and September and the leaves all dropped off. Thus we may have leaf dropping as a result of frost, injury by hail, root impairment or localized parasitic attack.

LEAF SPOT AND SHOT-HOLE EFFECTS

Leaf-spot symptoms are everywhere abundant and are really of very diverse origin. In any example in which the leaf tissues are locally invaded by a parasitic fungus we may expect evident effects. In the downy mildew troubles there may be wet-rot symptoms when the weather is moist, as in the case of *Phytophthora* or late blight attacking potato or tomato leaves; after the leaves have become badly diseased they may appear to die very suddenly because

the gradual invasion of the areas has been overlooked. In many other leaf diseases no such rapid multiplication or reproduction of the parasite is possible and limited dead patches or spots are the result. The leaf-spot disease of alfalfa, the various leaf-spots of apple and the conspicuous leaf-spot of the strawberry, the beet, the pea, etc., will be recalled. In these while the leaves are impaired as to usefulness they do not perish immediately and one may readily fail to estimate the injury at its real seriousness. In a few leaf troubles we have the spotting of the leaf followed by the formation of a separation layer in the leaf tissues between the parasitized and the healthy tissues. This results in "shot holes" in the leaves as is so very conspicuous in the shot-hole leaf disease of the plum and less conspicuously so on certain sour cherry trees. These leaf troubles are commonly very evident during rainy seasons and are preventable by spraying the foliage of the diseased plants at repeated intervals, thus keeping a supply of the fungicide on the leaves to arrest renewed spore development.

An interesting leaf-spot disease of the tomato is sometimes very damaging. This disease seems to have appeared in Ohio during the memory of many close observers. Like most leaf-spot troubles which are strictly due to parasitic fungi, this tomato disease has been worst in seasons of abundant rainfall. The same applies to the shot-hole disease of the plum and the allied leaf-spot of cherry. The explanation appears to lie in more favorable conditions for spore germination and for the growth or spread of the parasitic organisms which produce the diseased conditions. Biting or sucking insects also open the way for the entrance of parasitic diseases. (See later pages.)

LEAF IMPAIRMENT THROUGH FUNGUS COVERINGS

In addition to the leaf-spots or dead areas in leaves to which reference has just been made, we have most noticeable examples of the spread of the mycelium of certain powdery mildews over the leaf surfaces. Casual observers note that these spread over the leaves and stems of roses, over the leaves of lilac, of oak, of peach, of grape, of forcinghouse cucumbers, of bean and pea and upon other plants. While the development of these fungi or powdery mildews occurs often rather late in the season, they are nevertheless damaging to the host plant over which they spread. Above and beyond the interference with the leaf action the impairment of the photosynthetic or sunlight processes of the leaves of the plants by which all real increase in substance is made to the plants, these mildews develop sucking or penetrating organs of the threads of

the mycelium. These organs called haustoria penetrate the leaf epidermis and must do this for the purpose of food extraction—it is needless to add that all food extraction from the plant acts as robbery.

Furthermore, the mildew-covered leaves drop to the ground in fall and there afford the fungus the needed conditions for the development of the resting or winter stages of its course by which it is again ready to attack the plants the following season. Because so largely external in development these powdery mildews are usually comparatively easy of control.

WILT DISEASES—SEEDLING COLLAPSE

The stems or branches of plants may suffer from localized attack by parasitic fungi as well as from hail, insect attack and mechanical agencies. The symptoms which follow will be found characteristic. In certain ones as in the clover anthracnose and in the fusarium of clover stems, we have the lesions accompanied by discolorations in which the fungus occupies a subordinate place outwardly. On the other hand the spots or *sori* of the rusts upon grains and grasses and the spots caused by the anthracnose of wheat, oats, rye, etc. show commonly a crowded occupation of the area by the parasitic fungus.

There are many examples of the effects of such lesions. Fuller discussions will be found under the description of the particular diseases. The anthracnose of the bean as well as that of the pea are good illustrations where these attack seedlings. Even clearer symptoms come out in potato rosette where the fungus parasite at early stages of growth may kill off the stem attacked, while in later attack will cause such impaired development of the plant that stem or axial lengthening is arrested and a "rosette" appearance results. A still more striking arrest of stem elongation takes place in lettuce rosette wherein the roots are destroyed so largely by the fungus in the soil. (See soil infesting diseases.)

In cankers of branches upon orchard trees the final death of the immediate branch is preceded by a depressed area invaded by by the parasite.

PLANT DISEASES NOT BEYOND EXPLANATION

The old mystery attached to disease prevalence can scarcely be maintained in our day. We have worked out in recent years or had determined for us the causal relations between the ferment or parasite and the effects upon the host plant or crop. So far as we can now discover the reason for the spread of diseases, or of a

particular disease, is found in the specific disarrangements in the host plants. This discovery and announcement of these causal relations are undertaken that proper measures for the control of diseases may be finally devised and applied. We must always bear in mind that under favorable conditions plant diseases become epidemic and their rapid spread is to be expected.

The host plant, with its climatic adaptations and the parasites of our crops with their mutual adaptations to their hosts are biological factors which are capable of being influenced by prevailing atmospheric conditions. With cool, rainy weather we have brought about conditions favorable to certain parasitic diseases which will be inclined to spread while these continue. Other diseases spread under the conditions which favor them. The more rapid development of diseases of plants under these favoring circumstances is not beyond reasonable understanding; there is no mystery about it any more than in outbreaks of typhoid fever or diphtheria. By apprehending the differing conditions we may learn to separate the causal from the merely adventitious factors and thus be the better able to master the diseases which result.

While we may properly look upon infection by microscopic or other parasites as the general and usual cause of plant diseases, there are diseases of wide importance which arise from internal or physiological disarrangements in the plant. (See Enzymatic Diseases). In all cases whether of parasitic attack or of physiological disarrangement due to other causes, the host plant is weakened and predisposed to death.

GROUPS OF PARASITIC DISEASES

Parasitic diseases may be grouped in a way, according to the groups of fungi which cause them. This is helpful to the plant pathologist, though of limited practical guidance, since it requires microscopic study to determine the causal organisms. A more useful, limited grouping as is hoped, is proposed below and consists in making such groups or classes of diseases, as are descriptive of the general behavior. Such are seed infesting diseases, soil infesting diseases, root diseases, diseases of foliage, wound troubles, timber rots, etc. The great mass of diseases are treated under each host in the descriptive portion arranged alphabetically. The objects to be attained by this method of arrangement are obvious and call for no discussion.

NAMING PLANT DISEASES

Plant diseases are named with due regard to the symptoms and cause of the disease. In the case of enzymatic diseases wherein we have peculiar variations or yellowing of the leaves, the names given are more or less descriptive. The same applies to the diseases that are caused by freezing, hail, etc.

Parasitic diseases are named with regard to the organisms which cause the disease, or to the effects they produce in the host parts, that is, those diseases which result from attacks of the rust fungi, (*Uredineaae*), are properly called rusts; also the smutty, dirty conditions resulting from the attacks of the smut fungi, (*Ustilagineae*), are known everywhere as smuts; these are well known and destructive upon grasses and cereals. Thus we have smuts of oats, corn, wheat, broom corn, sorghum, millet, blue-grass, etc.

Fig. 2. Head or panicle of oats destroyed by loose smut. All the oat kernels and many of their surrounding parts have been converted into black, sooty (smutty) masses by the loose smut fungus, *Ustilago*.

The anthracnoses are produced by a definite class of fungi, (*Melanconiae*). The name anthracnose is applied to a disease of a given host caused by an organism of this group and the host name is usually retained, as the anthracnose of wheat, the anthracnose of rye, the anthracnose of raspberry, wherein the diseases are caused by species of this group of parasitic fungi. However, in the case of attack upon the fruit as in the anthracnose of apple, because of the bitter taste given to the fruit, we have the popular name bitter-rot; in a similar instance, viz., that of the anthracnose of the grapeberry, the discolorations of fruit are so characteristic that it is popularly called the birds-eye rot. With wheat, oats, rye, etc, the name is applied because of the organisms found. As stated in the preceding pages, we describe most leaf infesting diseases with regard to the effects the parasites have upon the host; thus we have the leaf-spot disease resulting from attacks of any one of a number of fungi, chiefly, however, belonging to the imperfect forms. The shot-hole fungus of the plum is a good illustration of the naming of a trouble from the symptoms produced.

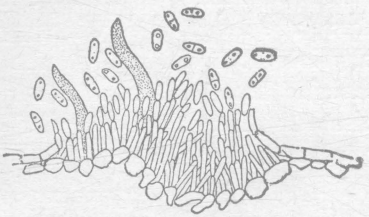


Fig. 3. Section through an anthracnose spot (*acervulus*) of the cucumber anthracnose fungus (*Colletotrichum lagenarium*) showing the long, dark hairs (*setae*) of whose office we know little, the spore bearing branches (*fertile hyphae*) and the spores of this fungus. The members of that division of the commoner anthracnoses having setae in the acervuli are referred to the genus *Colletotrichum*, while similar ones without setae bear the genus names *Gloeosporium*, *Sphaceloma*, etc. (See anthracnoses of apple, grape, lettuce, wheat, oats, etc).

A considerable group of diseases are known as downy mildews. Among these we have the destructive potato late blight and rot, *Phytophthora*; also the cucumber disease, *Plasmopara*, as well as the

grape downy mildew and the common white molds of the mustard family. The powdery mildews by reason of the appearance upon the surface of parts attacked, are descriptively named "mildews." A definite system has been followed in most cases of naming plant diseases and I trust the results will not be altogether disappointing.

The differences between the species of parasitic or other fungi are as strongly marked as those of higher plants, even though microscopic examination is necessary to distinguish these characters; it shows, therefore, that a discriminative system of naming diseases has a secure foundation.

THE PLANT OR HOST IN RELATION TO DISEASE

As stated elsewhere only closely related plants are usually subject to attack by a parasitic organism, thus it happens that the tomato as well as the potato plants are attacked by the downy mildew or late blight fungus of the potato. In general the true parasites among our fungi are limited to a rather narrow range of host plants; thus we may expect the potato *Phytophthora* to attack several plants of the potato family (*Solanaceae*). The writer proved this same was true of the attacks of downy mildew (*Plasmopara*) upon a number of species belonging to the cucumber family (*Curcurbitaceae*). Since our cereal grains belong to the same great family as the grasses (*Gramineae*), we expect, and find that there is a development of the same diseases upon many of them and upon the grasses growing nearby. In this connection it must be remembered that clover and alfalfa are not grasses, but legumes.

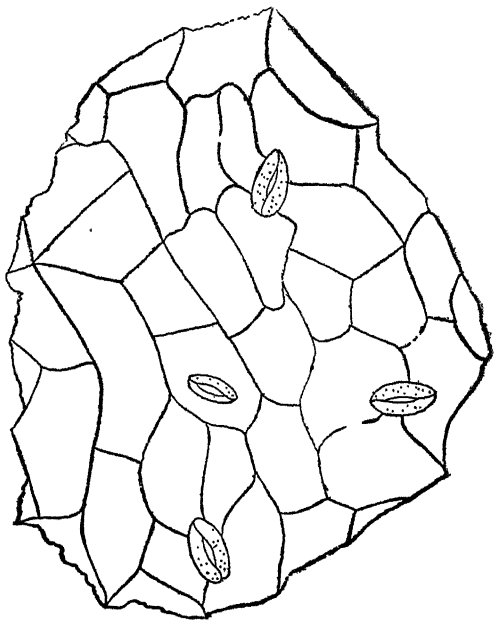


Fig. 4. A portion of the epidermis from the upper surface of a cucumber leaf, showing the breathing pores (*stomates*) surrounded by guard cells containing chlorophyll grains, much magnified. These guard cells, which control the opening and closing of the stomates, are the only epidermal cells that contain this green substance, the others being colorless.

The leaves of the host plant provided as they are with stomates or breathing pores, minute openings through the epidermal covering of the leaf, will be attacked through these openings. The spores

of parasitic fungi after germinating upon the leaf will likely gain entrance into the interior leaf tissues through these openings much more readily than by actual boring through the leaf epidermis.

The illustration, Fig. 4, shows how these openings are distributed in the epidermis of a cucumber leaf. These stomates are present in the leaf covering upon the outside of all green leaves and in the epidermis of young growing shoots. In addition to these stomates certain classes of plants such as the plants of the mustard family (*Cruciferae*), as cabbage, cauliflower, turnip, also the grape, fuchsia, impatiens, etc., are provided with water pores—marginal openings through which the excess water of the plants is excreted. These water solutions of various materials offer a means of growth for organisms, especially of the minuter forms. From the culture drops thus formed the parasite enters the leaf by the water pores. One of the most destructive known diseases of plants is the black-rot of cabbage, cauliflower, turnip, ruta-baga, etc. This is due to a bacterium which gains entrance very largely through the water pores just described. So we must bear in mind that the very avenues of transpiration or excretion, so essential to plant growth, are made a means of exposing the plant to the danger of parasitic invasion. This is analogous to the exposure of human subject to diseases of the respiratory organs. At every turn we find convincing evidences of the mutual adaptation of parasitic fungi to their host plants, in nothing more strongly marked than in the limitation of the species of plants attacked by a given parasite as discussed in the beginning of this paragraph. In view of the fact that so long as the leaves of a plant continue to function as leaves, these natural openings will be maintained, it will be seen that the risk of exterior infection from parasitic fungi is continuous for any given plant; it lasts for its whole growing period.

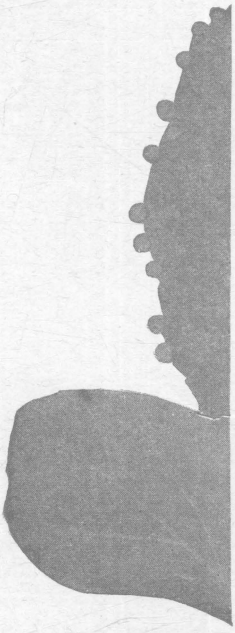


Fig. 5. Margin of cabbage leaf showing excreted water from water pores after cool night. These drops contain enough food for the growth of the black rot bacteria. The motile forms may swim through the water pores into leaf from such drops. Dead marginal areas on lower fragment show results of this bacterial infection. (After Smith).

THE PLANT'S PROTECTION AGAINST PARASITES

In the case of woody growths we have the development of corky epidermis or bark which seems primarily designed to protect the interior, living layer from invasions of this sort. In a similar

manner the external layer or bark of all growing plants, including herbs, is provided with a protective covering or epidermis. The skin of the apple or of the grape and the covering of the potato stem are all familiar and serve this function of protection to the inner tissues. In young plants there is retained the power of protective growth in response or resistance to parasitic attack; thus it happens that the potato scab organism induces the growth of cork cells on the outside of the potato and makes a roughness. The roughness is is not the scab fungus but the corky growth of the tubers in response to the scab attack. In a similar manner the attack of the scab fungus upon the apple results in the roughening of the apple skin through the development of more protective or wound cork. The most remarkable example of this multiplication of protecting or outer cells in response to the attacks of parasitic fungi is found in "leaf-curl" of the peach and in the pockets or "bladders" of the plum, where we have such a rapid multiplication of cells in response to the stimulus of the fungus as to bring about an entire transformation in the form and structure of the parts. While we may think of this abnormal development as the result of fungous growth, it is only indirectly so. It is in fact a response of the host to the stimulus of the invading fungus. The nature of the stimulus or excitation exerted by particular parasitic fungi is a highly interesting subject for investigation.

DISEASE RESISTANCE IN PLANTS

Disease resistance and disease susceptibility are as yet imperfectly understood. The cause of the inherent differences in the tendency of this or that variety to suffer, as with the leaf-curl in the Elberta variety of peach, the apple scab predisposition in White Pippin, Winesap and others, may become in practice, varietal weaknesses. Yet such is the commercial superiority of some such varieties that they increase in public favor despite these weaknesses. The great differences among varieties of fruit in susceptibility to the diseases which prevail under certain conditions, is a matter of observation and experience. From the difficulties involved in breeding a less susceptible or more resistant type of tree fruit belonging to any commercial variety, increased resistance is not yet within reach. This applies to established varieties and yet leaves the field open for new sports to be discovered or for its occupation by less desirable sorts which do not suffer so severely from disease. This actually happens in the growing of pears outside of certain favored districts; owing to the ravages of fire blight, a bacterial disease, the ordinary grower selects less popular but more resistant varieties for culture.

In the study of disease susceptibility it has been shown that other features being the same, the percentage of water is an index: thus, parts having the higher water content are attacked more readily than those with lower water content.

With annual plants or those reproduced each year by tubers or seed, the opportunities to breed resistant strains are extremely good and the results obtained are highly promising. Physiological weakness in plants may often be translated in terms of disease susceptibility; this holds with emphasis in vegetables and grains. Apparent physiological vigor may arise from various causes, and when expressed in terms of more rapid growth or higher water content or succulence of the parts may be indeed a source of weakness in the midst of disease. Selections made for the purpose of securing resistance to disease are made under conditions of *disease prevalence* with highest promise. This field of breeding for disease resistance is one of fruitful promise.

Studies in this line have been made by the Horticultural Department of the Station in respect to resistance of potato plants to the early blight disease. By selection of hills that withstood early blight attack and planting tubers therefrom and subsequent repetition of this work (See Bulletin 174) early blight resistant strains were secured. The differences between these strains and non-selected tubers in 1908 during the marked prevalence of early blight was very striking and clearly showed that a tangible resistance capable of reproduction has been secured. Owing to the wide extent of this field with vegetables and grains, much may properly be expected from breeding for disease resistance in the future. Much progress has been made with cotton resistant to wilt and with musk melons resistant to leaf blight. For the present other remedial measures will also need to be pushed.

CONCERNING PARASITIC FUNGI

A fungus (plural, fungi) is a plant, a member of the class called fungi. The fungi are low in the scale of plant life, being classed with the algæ and other similar plant forms. They are lower still in the life scale than the mosses and liverworts; above the mosses come the fern-plants, and above these the seed plants, such as grasses grains, clovers, trees, shrubs, herbs and the like, with which we come in contact every day. The fungi are distinguished from higher plants as well as from their nearer relatives, the algæ, by the absence of green color, and for that reason, we may assume, by the lack of power to prepare their own food from the mineral substances dissolved in water, and from the gases contained in the atmosphere.

Herein they are marked off from most groups of plants: the fungi must live upon the substance of living or dead plants or animals. If they ever possessed the power of utilizing the same foods as most other plants, this ability has been lost. Parasitism is usually taken to indicate degeneracy in character. One way of regarding the fungi is as algæ without chlorophyll, to which the latter owe their green color. As above stated, the fungi are, in the absence of chlorophyll, forced to live upon the dead remains of plants or animals, or to prey upon the living organisms.

CLASSES OF FUNGI

Such fungi as subsist upon living plants or animals are called parasitic fungi. A parasite is one who eats at another's table and the adjective "parasitic" comes from this word, parasite. It is the parasitic fungi especially of which we must learn, since this class produce diseases when they attack other plants. The plant attacked is the "host" plant, however unwilling the entertainment of the sycophant.

Most fungi are very minute in size and require the use of a microscope to study their parts; certain ones, however, such as the mold upon bread or other foods, may be seen very easily to consist of fine, thread-like growths interwoven together, and bearing certain rounded parts upon erect branches. Some idea of fungus-structure may be obtained by studying these common molds; that on a discarded melon rind will shows the parts above described, and by the use of a microscope we may learn that the rounded, ball-like enlargements just mentioned consist chiefly of small bodies that are capable of growing into other fungus-threads. (Fig. 6). Such minute parts capable of germinating and again producing the fungus are called spores. Most spores are very minute and are not heavier

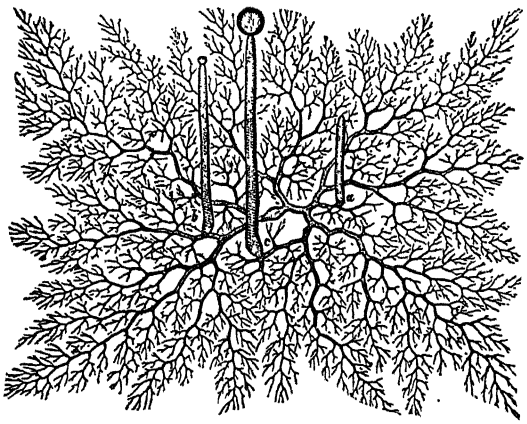


Fig. 6. Mycelium of the common mold (*Mucor Mucedo*). From the spore lying near the middle of the figure, and strongly swollen, one sees the thick threads of the mycelium arise; these in turn become richly branched. There are no divisions in the mycelium. From the level of the mycelium arise three vertical fertile hypae, *a*, *b*, *c*, of which *a* is still very young and that at *b* is already producing a sporangium containing many spores. All highly magnified. (After Zopf, from Reinke).

than the other dust particles carried by the wind. The spores of fungi are the means by which these are most commonly reproduced, somewhat after the manner that the higher plants about us are reproduced by their seeds.

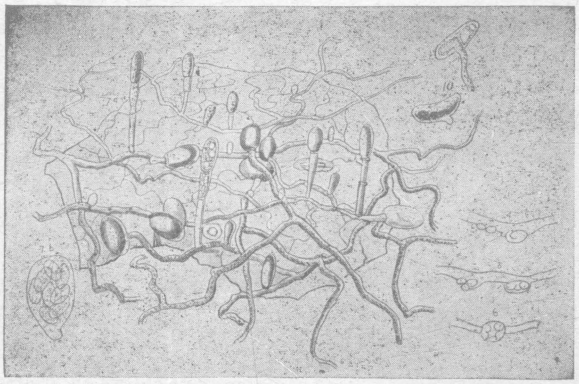


Fig. 7. 7*a*. A portion of leaf of pea showing breathing pores and parasitized by powdery mildew; the horizontal threads (*sterile hyphae*) and summer spore bearing parts of the mildew fungus (*fertile hyphae*) are distinctly shown. In these latter the septa are evident. 7 *b*. A spore sac (*ascus*) of the same fungus. 4, 5, 6, show the sucking organs (*haustoria*) of the sterile hypae of this fungus; these penetrate the epidermis of the leaf. 10 shows the spores of the rose mildew germinating. All highly magnified. (After Tulasne).

Note—The stomate in foreground is distorted. See Fig. 2.

While we have cited the bread mold as a good illustration to show the structure of a fungus, it is not a parasitic fungus; a mold or like growth which lives upon decaying material is called a saprophytic fungus. To this same belong the mushrooms or toadstools that may be found in manure piles, in the woods and in orchards; the fact that we find them in such places shows that there is decaying organic substance at that point, upon which these plants may subsist. A like condition is found in the shelf-fungi on old logs and stumps, on the under surface of which we may write our names. Yet if we will use a hand lens we may often discover this under surface to be but a network filled with small openings or pores from which the spores of the fungus will in time escape. In like measure the spores of mushrooms are found in similar canals or upon the sides of the gills beneath the cap of this sort of fungus. The bacteria, or fission fungi, are one-celled plants multiplying by division and by spore production; with bacteria evident mycelium is lacking and they are structurally lower in the scale of plant life than fungi provided with a mycelium. Bacteria are both parasitic and saprophytic. But to return to parasitic fungi:

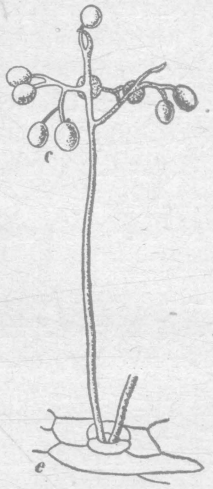


Fig. 8. Fertile hyphae (*conidiophores*) of the downy mildew fungus on *Cardamine*, a mustard protruding from a stomate; the one shown in full, bearing spores at the end of its branches. Highly magnified. Very similar to this are the downy mildews of grape, cucumber, lettuce and some others. (After Zopf).

PARTICULAR FACTS ABOUT PARASITIC FUNGI

Like the bread mold, or the other fungi just mentioned, parasitic fungi consist of a growth of threads or hyphae (singular, hypha) which do the necessary work of getting food for the parasite; these also in due time give out certain branches destined to bear spores, somewhat after the manner that the pear tree has flower clusters, or the wheat plant forms its dense spike of bloom, both of which are especially designed to produce seeds from which wheat plant and pear tree may in turn be grown. The essential parts of a parasitic fungus are these threads, or hyphae, and the spores produced by them. The hyphae of the fungus taken collectively are called the mycelium, which consists of threads that produce no spores (sterile hyphae) and of those destined for spore production (fertile hyphae. (Figure 7). It is to the food getting qualities of the hyphae that the fungus owes its continual existence, and they in turn arise from a spore or directly by the growth of some fragment of fungus-thread, as the Carolina poplar may be grown from a cutting. Yet, while all parasitic fungi are made up of these few parts, the differences in form and apparent structure among the several groups are very marked; differences exist as to the thickness of the hyphae whether or not the threads are divided into separate cells by divisions like those at the joints of a bamboo rod, as well as in the manner of spore formation and in the size, color, form markings and structure of the spores themselves. It is almost hopeless to undertake to illustrate types of spore production and spore forms, since these are so varied and may differ so much at different stages of the development of a single given species of fungus, yet we may cite a few examples:

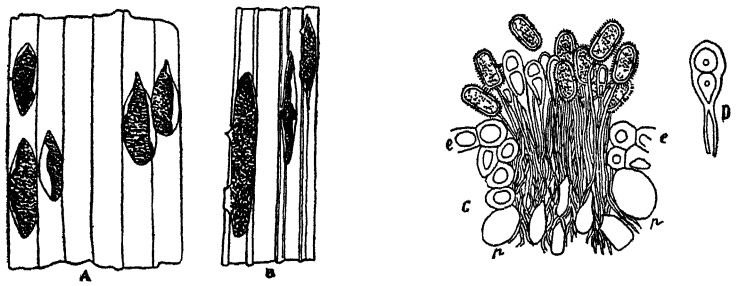


Fig. 9. Showing the common rust of oats and rye. At *A* a small fragment of rye leaf with several orange-red, rust sori breaking through the epidermis; these are of the earlier summer spores (*Uredo*) or red rust of popular speech. At *B* a small fragment of a rye leaf with several black, rust sori, elongated in form, breaking through the external covering; these are of the later summer or winter spores (*Teleutospores*). *A* and *B* slightly magnified. At *C* section through the uredosorus of *A*; on the slender stalks (*basidia*) the rough one-celled uredo spores, and between them a young, two-celled teleutospore, which later alone form the sorus. *e*, *e*, epidermal cells; *p*, *p*, cells of the leaf interior through which runs the mycelium of the fungus. At *D* a teleutospore from the black sorus of *B*; this is divided by a septum into two cells. Similar uredospores are found in most rusts; similar teleutospores occur in corn rust, wheat rust, etc., and in the spores of the cedar apple fungus. *C* and *D* considerably magnified. (After Zopf, from Frank).

Fungus spores may be produced as single spores or in naked clusters attached to certain branches. We find this sort in the downy mildew of the cucumber and its relative the peronospora of mustards (Fig. 8); in potato early blight; in fruit rot of plum, cherry, peach, etc., and later in the spores of apple scab. They may also be found in dense clusters breaking through the skin of the plant like the many tubers of a potato breaking through the earth-crust; such without further conspicuous covering are found in the rust spots, in the anthracnoses and the like. (Figs. 3 and 9). These dense clusters may arise beneath a special covering resembling nothing so much as the traditional beehive, but are usually ejected forcibly from a specially provided opening at the top of the cone or half-ball. (Fig. 10). A yet more interesting class is that in which the spores are packed so many to a sac (usually eight) and a large number of these crowded into a ball-like, hollow spore-case, such as we find in black-knot, strawberry leaf-spot, the powdery mildews and in some other instances. (Fig. 11). There is yet another sort in which the spore sacs are abundant near the surface of the diseased part, as in leaf-curl of the peach, where the maturity of the fungus is shown by the change in color of the affected leaf surfaces. Other gradations will be found as one proceeds in this study.

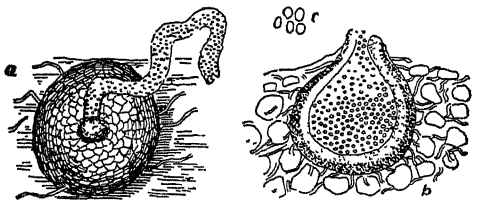


Fig. 10. *c*, spore case (*pyenidium*) of a beet leaf-spot fungus (*Phoma*) seen from above and showing the slender, flexuous mass of spores, ejected from the pycnidium. *b*, section of a pycnidium, seated in the leaf tissues and filled with spores. *c*, a group of the spores. All highly magnified. (After Allescher from Delacroix).

THE SURVIVAL OF PARASITIC FUNGI

Further, respecting parasitic fungi we must realize that they are all derived by specific processes of reproduction peculiar to the fungus in question; in other words spontaneous generation does not find support among the students of plant diseases.

The presence of any given fungus leads us at once to infer the previous existence, somewhere within reach, of a fungus of like species from which this one was derived by definite methods of reproduction. Likewise, the destructive prevalence of a parasitic fungus in any given time and at any given place, assures us of the necessary supply of spores to start the trouble again under favorable conditions. In fact, all our study leads us to look through mere phenomena, mere evidences of disease, to find the specific parasitic growth which causes them and the favoring conditions under which

these develop. The spores of fungi serve for them the same purpose as do the seeds in higher plants; by reason of the extreme smallness of the spores they are easily transported by the wind and become deposited like dust particles upon exposed surfaces. Certain resting spores survive on the fallen leaves or other parts and will be destroyed if these parts are burned. (See black-knot). The survival of organisms capable of infecting the new crop is certainly to be expected in plant diseases as in epidemic disorders among people.

Some fungi which produce disease survive by their thread-like parts (*mycelium*) in a manner similar to the survival of Canada thistle quack-grass and the mints among troublesome weeds by their visible underground stems. A good illustration of this form of survival is found in the case of potato rosette; in this disease the masses of mycelium (*sclerotia*) remain upon the surface of the potato tubers and unless destroyed by treatment of the seed will be ready for immediate attack upon the growing plants (sprouts), even before these have reached the outer air and taken on a green color.

Similar survival may occur in cultivated soils, especially where the same or closely allied crops are grown in succession. Thus the same fungus as that of the potato disease first named, survives in greenhouse soils or in celery soils outdoors.

RESTING FORMS AMONG FUNGI

The active parasitic phases of fungi necessarily coincide with the activity of the host plants; it, therefore, follows in our temperate climates with alternating periods of activity and rest of growth and practical somnolence, that the parasites require to be mutually adapted to intermittent activity. Some spores will survive the brief rest period between harvest and seed time, as in a number of the various grain smuts and in grain anthracnoses. Here they are found simply adherent to the seed grain.

Seed infesting parasites like the loose smut of wheat, the anthracnose of pea and bean, and a variety of other vigorous species survive as resting mycelium, which remains virtually inactive so long as the parasitized seed is not exposed to conditions of moisture and temperature such as bring about germination.

There are endless gradations between these instances of "resting" mycelium and the protected fruit cases of the higher type of fungi. Thus the perithecia or closed fruit bodies of the wheat scab fungus, develop shortly after harvest upon the infected glumes or culms of wheat, and may be observed by the unaided eye, as black bodies seated upon the pink mass of the summer form. These fruit bodies in this case are the kind called "perithecia," which contain

within them spore-sacs of a nearly fixed number and each sac contains a fixed number of spores of definite form for each species. A great many fungi develop these "housed" or protected forms during the dormant period, and indeed, spore development may proceed in the periods of lower temperature.

With the perithecial or sporehouse form of wheat scab, (*Gibberella*), the spore sacs are formed during the later summer, in our latitude, and these spore sacs disappear before midwinter. For each genus or species under study, peculiar time relations of development may be discovered. The perithecial or spore sac (*acsigerous*) form just described, or some comparable development of the spores under a definite cover-form, is viewed as a more or less ultimate stage in the development of the higher fungi — the summit in the cycle of their development.

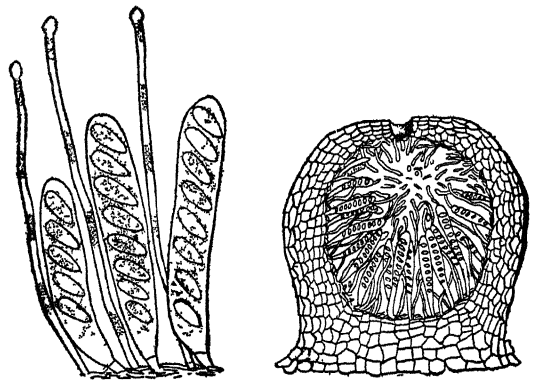


Fig. 11. Section through a spore case (*perithecium*), late winter stage of black-knot fungus, showing spore sacs (*asci*) within. Beside it, three asci containing winter spores or ascospores, eight in each sac, arranged in a definite manner. Along with these are thread like hyphae known as paraphyses

The rot of stone fruits, such as peach, plum, cherry and the like, is commonly known only in its conidial development called *Botrytis*. Recently Norton has discovered the *Sclerotinia* or ascigerous stage developed from the mummy fruits in which the fungus lay dormant for a time awaiting spring or summer conditions.

The bitter-rot of apple and its cycle of development not long since brought to light in Illinois, also shows the relation of the apple mummies, decayed by attacks of this anthracnose, to its survival. The fungus lives over in the old rotted fruits, acted upon by bitter-rot alone, which hang upon the trees. The fungus may also survive in branch cankers upon the tree adjacent to mummies of the bitter-rot. In these branch cankers the spore sac or perithecial stage of the fungus is developed. Upon the coming of warm showery weather about early June, new spores are produced from either mummies or cankers and new infection may occur upon the new fruits. The problem of the control of this disease, therefore involves a knowledge of its manner of survival.

ALTERNATION OF HOSTS IN FUNGUS SURVIVAL

This relation of alternating forms in the life cycle of a given parasitic species, to its survival, has been mentioned in wheat scab wherein we have the *Fusarium* or pink mold and the *Gibberella* forms; in rot of stone fruit where we find *Botrytis* and *Sclerotinia* forms, and in apple anthracnose or bitter-rot where we discover the *Gloeosporium* followed by the *Glomorella* ascospores. In these instances there seems no real need for the advent of *another host plant.* In other groups of fungi, notably among the *Uredineæ* or rusts, we discover in certain species, that survival is accompanied by a necessary change of host plant. The apple rust is known in summer to attack the leaves and fruit of apple, thorn apple (*Crataegus*), june-berry and mountain ash. This is the aecidial or cluster-cup stage of the apple rust and has its counterpart in the aecidiospores or cluster-cups of the wheat rust upon barberry as well. With apple rust we climb far on the plant ladder and find the teleutospores of rust survive upon the cedar trees as branch enlargements called cedar apples (*Gymnosporangium*). The dry looking apples upon the cedar trees take on a new form during spring showers when they become great, jelly-like masses which emit the teleutospores of the rust, to be carried to apple, juneberry and crataegus leaves by whatever agency is available.

The relation of cedar trees to the prevalence of apple rust is a practical matter for each orchardist. It may be better to make firewood of the cedar trees than to combat the apple rust in his orchards. A similar problem as between the barberry hedges which adorn rural England, and the virulence of wheat rust in their grain fields, may also be raised. With us we have plenty of grain rust in the absence of barberry hedges. An adaptive form of survival apparently takes the place of the alternating hosts, and we still have the wheat rust.

The instances given are simply illustrative and the student of plant pathology will discover many more in the course of his study. Likewise a careful perusal of the special part of this bulletin will show other instances of survival under many various and instructive conditions.

HOW THESE PARASITES ROB THE HOSTS

There is an old saying about the stable door and the stolen horse; similar application may be made for plants and parasitic fungi in a manner which we shall presently perceive. To obtain food we must reach the source of supply; the manner of reaching it is less important than the result. Now it occurs that cultivated and wild

plants of the higher classes are wrapped about by a covering of skin or bark, and the food-filled juices are within; to feed upon any living host the parasite must gain access to the internal tissues of that host. It so happens that there are minute openings or stomates (breathing pores) through the skin of leaves and of young green stems; these openings are as necessary as the stable door, and through them the thief may enter. (See Fig 4). Were these openings to become entirely closed the plant would languish, and remaining open, they constantly offer a way for the tender tip of the growing germ thread of a fungus to push its way through the plant covering and to luxuriate within the host upon the substance of the plant. Once within, the fungus thrives, rapidly multiplies its branches, and if in summer, commonly thrusts its fertile threads through some of these breathing pores to bear its spores outside where they may become more widely distributed than if remaining within the tissues of the host plant. Should, however, the winter season be near, resting spores may be formed, or their formation be provided for within the leaves, or diseased parts, as in grape downy mildew, elm-leaf disease and in black-knot of plum and cherry. Thus the cycle of development continues indefinitely unless some agency intervene to destroy the spores, to prevent their germination, or the parasite itself so exhaust the host plant as to destroy it entirely and the fungus perish for lack of suitable nidus. However, this rarely occurs, not perhaps, so often as men are guilty of killing the goose which lays the golden egg. Herein, we meet another fact, namely, that parasitic fungi of a given kind are limited to a particular host plant of a certain species, or to a small number of related plants, so that if a congenial host is lacking the fungus will not thrive.

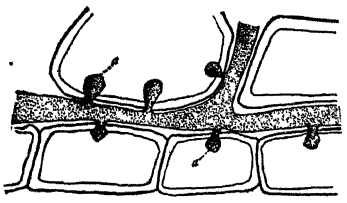


Fig. 12. Haustoria of the fungus of the grape downy mildew penetrating cells of grape stem. The shaded portion shows the mycelium of the fungus growing between the cells, sending haustoria, *a a*, into the interior of the cells. (After Scribner from Farlow).

Note: In this figure the lower row of cells have the form of empty epidermal cells in which the fungus would find little to subsist upon. Farlow's original figure does not give these cells such form.

The fungus threads growing within any plant will not flourish if simply passing between the cells of the host; penetrating organs pierce the cell walls and are able to absorb nutriment from the cell interior. (Fig. 12). The diverse forms of sucking organs, and the peculiar structures of fungus threads in these situations would in themselves require much study and investigation to present them properly. We must further conceive that a fungus may often

penetrate the bark of a tree for example, if aided by rifts caused by freezing or similar disturbances, to say nothing of the openings offered by wounds, the breaking of branches, etc. A recent illustration of the danger of rifts in the bark of trees is offered by the chestnut disease which is proving so destructive near New York City. Few parasitic fungi have that penetrating power of thrusting the haustoria through the plant covering such as we find in the case of the dodder that twines about and robs the wild herbs and shrubs of the woods and fields as well as the cultivated flax and clovers.

HOW PARASITIC FUNGI AFFECT THE HOST

We know the cumulative effects of insufficient food supply; these effects must hold for plants attacked by parasitic fungi. Aside from the nutriment diverted to the parasite, there is reduced functional vigor of leaf, stem or root, and the loss becomes increased in this way. Let all the leaves be parasitized, or let even three-fourths of them be entirely so attacked, and we may look for great loss of foliage, possibly entire loss of fruit and the detailed effects of diminished vigor, unripened wood, or by repetition, entire destruction of the host. Usually the effects are of many gradations, but in all cases of leaf parasites the entire plant must suffer. We have learned that bacteria may, in a suitable medium, destroy themselves by the formation or emission of poisonous products which are fatal alike to the bacteria and to animals, or even man; that such takes place within plants parasitized by fungi remains in doubt, and may be disregarded for the present. The results of impaired function in the parts are serious enough to demand our attention. It is altogether probable that future investigations will modify our views upon some points.

There are many curious transformations and malformations resulting from the attacks of parasitic fungi, simply by the multiplication of cells of wound cork or other tissues in the effort of the host to shut off the fungus, not because the fungus consists of such a mass of tissues. (See leaf-curl of peach).

While exceedingly interesting to trace the effects of the white mold on shepherd's purse and on the garden purslane, as well as the effects of bramble rust, cabbage club-root and a number of others, the principle above pointed out will be found generally applicable, and it is to the reactions of the host plant that the excrescences or malformations are chiefly attributable.

It may further be stated that artificial cultures of parasitic fungi, either upon culture media or living plants are constantly adding to our knowledge in these lines.

BENEFICIAL ORGANISMS: ROOT NODULES, ETC.

While realizing the losses caused by parasitic fungi and bacteria we may not hastily condemn all fungi and bacteria. One of the most profound influences of aging culture of the soil is the beneficial

effects in nitrogen fixing, exerted by the root nodule bacteria of leguminous plants. The well known beneficial effects of the root nodule bacterium upon clover has made rotation in clover an agricultural necessity. The species or forms of root nodule bacteria required on alfalfa, cowpeas, vetches, etc., have become recognized as factors of consequence in our efforts at seeding and new species of legumes on the farm.

A less understood relation between certain fungi which develop as mycorrhiza upon the roots of some deciduous trees and notably on conifers may not be passed. Herein we may find an explanation of rotation in forest species when reforestation crops are to be grown.

THE PROOF OF PARASITIC CAUSE IN PLANT DISEASE

The mere presence of a fungus, determined by the microscope in diseased tissues of the plant, does not prove the case against the organism found. It is not easy at all times to be certain whether discovered spores belong to this or that organism, or group of organisms, although with certain groups as the anthracnoses, species of Fusarium, etc, the spore forms give somewhat clear evidence. The differences between parasitic and saprophytic fungi are not always simple matters admitting of ready determination; further, we must bear in mind that after a parasite has caused death or even minor lesions in a plant, the organisms of decay may be expected to appear to do their great work as the scavengers of the world. The fungi or bacteria found in a dying plant may be both saprophytic and parasitic, or these may be only saprophytic.

The methods of proof of parasitic cause in the bacterial diseases of animals including man have been extended to the study of bacterial diseases of plants and finally to the diseases caused by parasitic fungi. These methods consist of a group of rigorous exact rules which are stated by Dr. E. F. Smith in the following terms:

(a) Constant association of the organism with the disease.

(b) Isolation of the organism from the diseased tissues and careful study of the same in pure cultures on various media.

(c) Production of the characteristic signs and lesions of the disease by inoculations from pure cultures into healthy plants.

(d) Discovery of the organism in the inoculated, diseased plants, re-isolation of the same, and growth on various media until it is determined beyond doubt that the bacteria in question are identical with the organism which was inoculated.

Smith—Bacteria in Relation to Plant Diseases. Vol. 1, p. 9.

While these methods and rules are stated with special reference to bacteria as the cause of disease, they apply with equal force to the proof of cause in the case of any given parasitic fungus. These methods require rigorous and exact work in the isolation and subsequent culture of the parasite upon sterile media, followed by equally careful inoculation work using these pure cultures as a source of the organism.

METHOD OF INOCULATION FROM CULTURES

The methods of inoculation tried by the investigator are of great importance. These determine, in fact, the success or non-success of his efforts. There must be adaptation of the method to the life history of the parasite and the developmental stages of the host plant, including the appearance of the parts more commonly attacked by it.

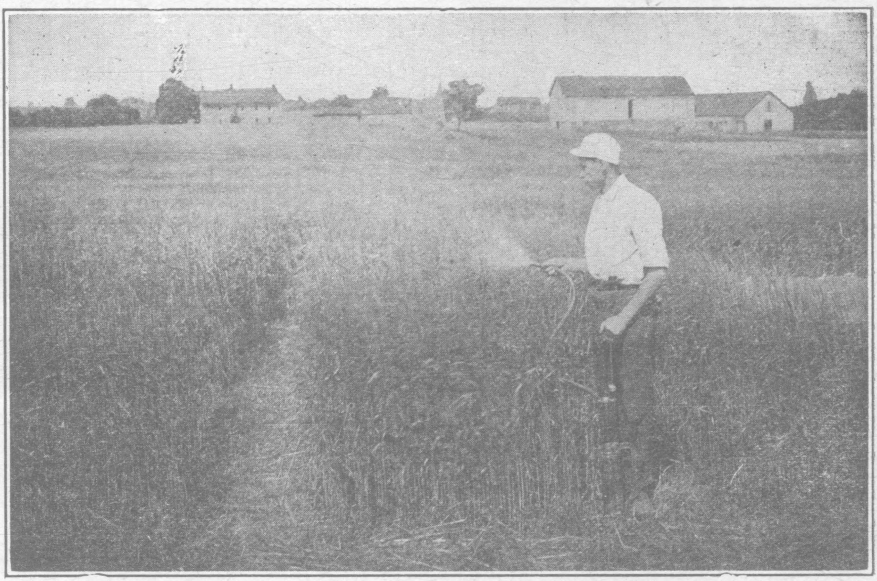


Fig. 15. This shows method of infecting field plots by means of the hand spray pump, using the washings of samples of wheat and other grains. The washing of grain containing spores of disease such as anthracnose or scab may be used. Cultures may also be sprayed upon plants in this way or by means of blow-bottle in smaller tests. (From Bul. 203, Ohio Experiment Station).

Following the methods of earlier bacteriologists, needle pricks are often employed both in the inoculation of fungi and bacteria into plants. One seeking to pursue a special line of inoculations will need in all cases to study his conditions as well as the methods of other investigators. Thus, doubtless, inoculations like those of Phytophthora and Plasmopara may be best attained by using drops of sterile water to carry the spores. The same principle applies in field

methods upon many crops. In the case of grain diseases, notably anthracnose and scab upon wheat, rye, oats and grasses, inoculations may be made by spraying the cultures upon the grain at a proper stage of its development.

While some groups of fungi do not lend themselves readily to culture upon the usual media, it is the aim of plant pathology to make this possible with a constantly increasing number of these parasites.

CULTURE PROOF NOT ALWAYS POSSIBLE

While in all cases of bacterial diseases where the body of the organism is so little different from that of the bacteria of decay, fermentation, etc., these rigorous proofs are required before the disease is listed as of proven bacterial origin, we do not find it necessary in practice to reprove again the case as against frequently occurring species of fungi associated with particular plant diseases. This does not make it less necessary to prove all cases as to parasitic cause, although the practicability in any single laboratory of pathology is admittedly one of narrow limits.

ENZYMATIC DISEASES OF PLANTS: CHLOROSIS OR PANACHURE

To this form of physiological breakdown, induced however, by specific causes recently determined, we attribute some very widespread and injurious diseases which belong under the head of chlorosis. Peach yellows, possibly peach rosette, frenching or mosaic disease in tobacco, and in general variegated or special yellow foliage types of plants as in Arundo, Acer and other genera of plants belong here. The yellows in peach has long been studied, as also the tobacco mosaic disease. In yellows the contagious character of the disease and its transmission in pruning by contact of parts of the harness of team and by or through the atmosphere has been recorded.

A few years ago it was determined by Beierjink and by Hunger that this infection exists as a chemical compound or compounds of complex nature belonging to the oxidizing ferments of a group called the oxidases. Oxidase, peroxidase and others of these ferments are known. They act by breaking down or oxidizing the plant leaf tissues and especially the chlorophyll or leaf-green of foliage and young tissues, converting it into xanthophyll. The tests for these ferments are of some importance. Woods and others have shown their action with peroxid of hydrogen.

From a practical point of view the transmission of the ferments, and, therefore, of the disease, by touching first diseased and then healthy foliage is rather surprising. The work of Hunger in Java

upon the transmission of the tobacco mosaic disease makes the risk of transmission from diseased to healthy plants by such handling, stand out clearly. This line of transmission was verified on tobacco by the writer's assistant in 1903 (See Bulletin 156, of this Station).

While the same class of proof for peach yellows is very difficult, owing to the latent nature of the disease for some months after first infection, the actual results of infection from nearby diseased trees make clear the danger of such exposure and the necessity for the destruction of diseased trees. Chemical examination of variegated or chlorose tissues shows the same compounds, the oxidases, etc., to be present and to account for the transformation of the leaf-green or chlorophyll, into xanthophyll, or leaf yellow. Thus by degrees apparent plant disease mysteries are solved. The weakness of variegated plants and their ready susceptibiity to attacks of parasitic fungi are now explained by this impaired condition of the leaf parts.

PLANT DISEASES TRANSMITTED IN THE SEED

The public in general little realizes how many diseases of plants are transmitted in the seed, although as the years pass the general dissemination of knowledge concerning infection by spores and by germs has partly prepared the way. The public mind does not longer expect something to grow from nothing. The treatment of seed grain, as wheat, oats, barley, etc., to destroy adhering spores of the smut fungi, and thus prevent these smuts in the crop, has been known for many years. In the early days of the Agricultural Experiment Stations, these doctrines and practices in this regard were widely disseminated, new impetus being given by the successful use of hot water following the methods of Jensen in Denmark; but despite the conquest of the practical control over the order Ustiligineae, the smuts, we have only really begun to study the matter of seed infecting diseases produced by seed infesting fungi. These seed infesting fungi are of two types, viz, first, those whose spores adhere to the seed grain as in the case of the smuts of grains generally, and second, and more exactly, those fungi which develop upon or within the seed largely by their threads or mycelium, and may, or may not, prevent the germination of the infested seed grain. Our knowledge of these strictly seed infesting fungi is quite recent; we may point to the work of Prof. Bolley and his assistants at the North Dakota Experiment Station, especially upon the matter of flax diseases; to the work of Dr. Halsted in New Jersey and to Bulletin 173 of this Station by Van Hook. With the tendency to continuous growing of flax, in the west there was developed a

that new area specific seed and soil troubles which have been proved to be perpetuated in the infected seed. An anthracnose of flax and a Fusarium attacking flax seed are examples.

No less conspicuous is the case of the blight fungus of peas, *Ascochyti pisi*, which is also an anthracnose, and the allied anthracnose of beans, *Colletotrichum lagenarium*. Investigations made at this Station by Van Hook show the source of the trouble with peas to be the infected seed employed and show also that seed treatment will not destroy these internal fungi without destroying the vitality of the seed. It was further shown that the source of relief lies in growing healthy seed through the use of fungicides upon the pea vines from which seed is gathered; likewise that infection may remain in the soil, (See Bulletin 173).

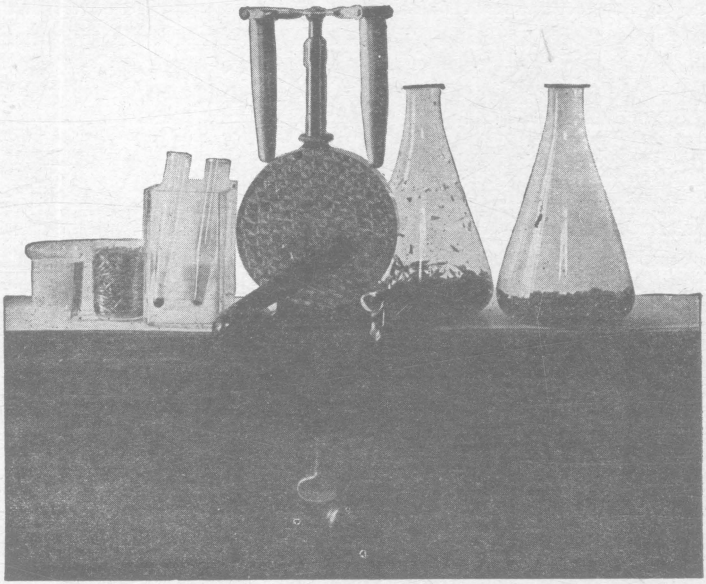


Fig. 14. Showing physician's centrifuge and other apparatus used in making examinations of grain washings for smut spores and spores of other diseases adhering to the exterior of seed. The flasks at the right show samples of washed grain. Those at the left show amounts of grain and water used. The glass tubes in container are used in the metal holders of the centrifuge. The precipitates in bottoms of tubes were obtained from washing of oats and wheat samples in flasks. (From Bul. 203).

More recent work at this Station has shown the presence of seed infesting and seed infecting diseases in wheat. (See Bulletin 203). The illustration, Fig. 15, exhibits the germinating seeds of wheat with the outgrowth of the parasitic fungus (*Fusarium*) which we find associated with wheat scab. This is upon seed grains (kernels) that are not destroyed by the fungus; many of the kernels of scabby

heads will not germinate. It was also found in continuous wheat land as much as 6 percent of the young wheat plants were destroyed in the fall by this same parasite which appears to survive in the soil under continuous wheat growing as well as to be propagated in the seed grain.

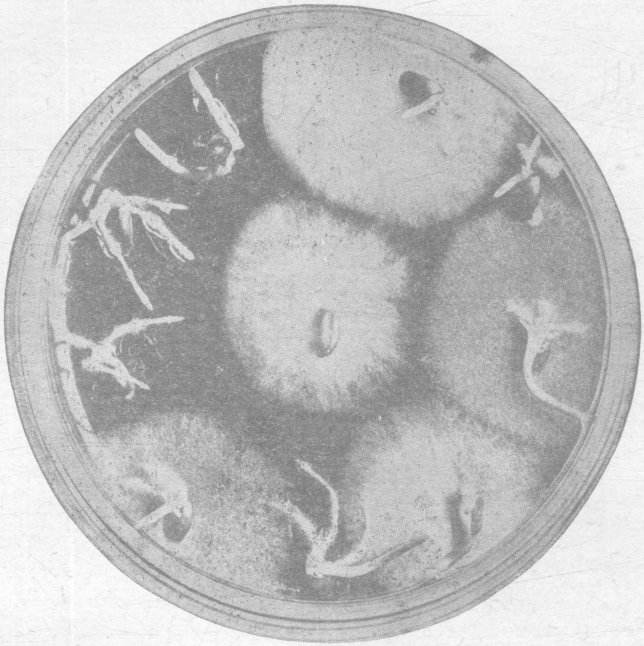
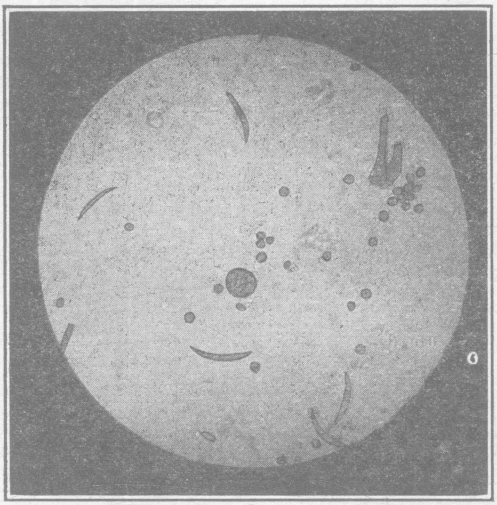


Fig. 15. This shows results from germinating ten wheat kernels in Petri dish containing agar. Both the agar and the kernels were sterilized. After five days it was found that five kernels had produced healthy plantlets, and four kernels had germinated but were attacked by the scab fungus, *Fusarium*, and two by another fungus. One kernel in the center did not grow and gave only growth of the scab fungus, *Fusarium*. (From Bul. 203).

HOW TO EXAMINE SEEDS FOR INFECTION

Recently good success has been obtained in the laboratory of this Department in determining the presence of certain seed infesting fungi in seed wheat, oats, rye, etc. In regard to the matter of adhering spores this is accomplished by making washings of the seed in distilled water and separating the spores from the washings by means of a physician's centrifuge. (Fig. 14). The spores and similar particles washed from the seeds are thus collected in the bottom of the tubes of the centrifuge and may be identified by microscopic examination. (Fig. 16).

Examples may be multiplied to illustrate the range of seed infection both by adhering spores and by internal development of the mycelium of the invading fungus. Many of these are treated under the particular diseases of the crops. The bean, pea, barley, broom-corn, flax, millet, potato, sorghum, rye, sweet-potato, and wheat will all furnish examples. Not only have we to test the actual survival of the parasites thus found but we must discover the behavior of the disease with respect to the germination and seedling plants which grow from such infected seeds or tubers. Examination for infection of seed bulbs and tubers may be made either with or without the growth of plants from them. With potato scab and rosette, the external scab effects or the sclerotia of *Rhizoctonia* are not difficult to see. With the latter the moistened tubers show marked color contrasts and make the work easier. These diseases are reached by seed treatment.



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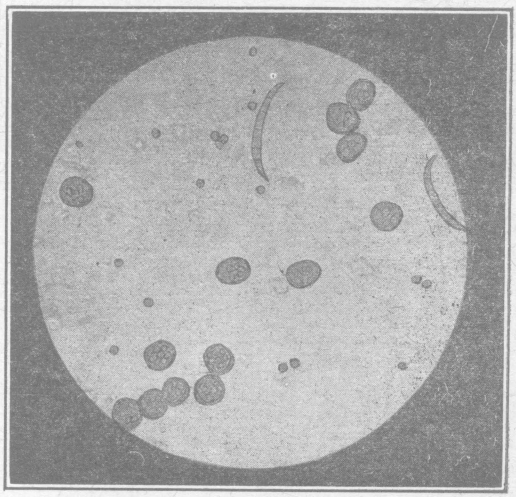


b

Fig. 16. Microscopic photographs from centrifuge precipitates of wheat washings. *a*, from wheat washings, narrow, slightly curved anthracnose spores, small spherical, loose smut spores, large spore of stinking smut and portions of the setae of anthracnose. *b*, from wheat washings, small, loose smut spores, large stinking smut spores and curved scab spores. All magnified about 180 times.

Where the infection is internal by the threads or mycelium of the fungus, the seeds may be germinated in Petri dishes where the kernels are surrounded by a moisture retaining, sterile medium

such as agar or gelatin. This method has been worked out in Bulletin 203 and may often be applicable. The illustrations above will show the results in these cases as before referred to. With internal tuber infesting diseases as in the bacterial wilt disease of the potato, the Fusarium wilt or dry-rot fungus of the potato and the soil-rot of the sweet potato, we must go further than mere external examination. For the two named wilt diseases of potato, infection usually shows earliest at the stem end. Thin slices across this stem end of the tubers will show whether or not there is discoloration in the vessels. In the absence of infection there will be no discoloration with bacterial infection by *Bacillus solanacearum*, black areas or rings will be seen in these tissues while tubers infected with *Fusarium oxysporum* will show local areas of browned or blackened tissues. This infection applies usually to harvest time. As the infection advances, one-half the length of the tuber or even more may become infected. In all cases sections from sterilized tubers may be used as a source of cultures in Petri dishes. The same applies to soil rot of sweet potato. These diseases are not reached by seed treatment.

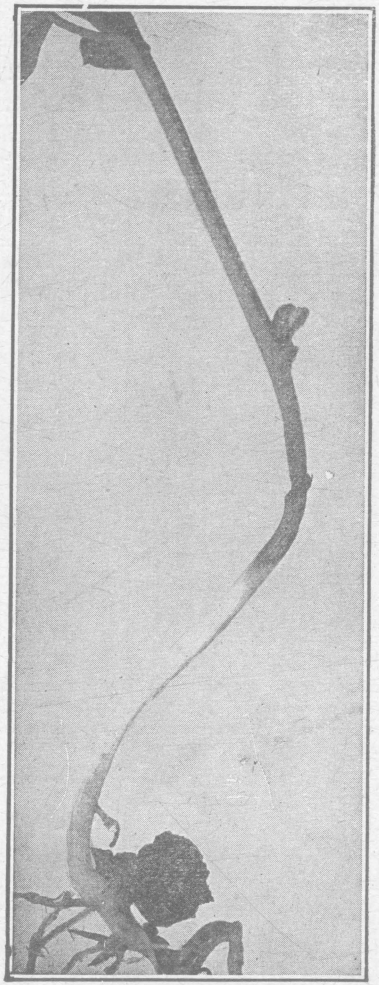


Fig. 17. Pea stem showing lesion from blight fungus, *Ascochyta pisi*, near surface of ground. This fungus came from the seed pea. (Natural size). From Bul. 173.

THE LIMITS IN SEED TREATMENT

It will be apparent that serious limits hold in regard to seed treatments. Where the spores are external and simply adhering to the seed grain, treatment will destroy these spores if rightly adapted to the seed in question and the germination need not be much, if any impaired. On the other hand where the seed infection is internal rather than external, grave doubts arise as to the possibility of successful seed treatment.

It has not been found possible in the cases of seed peas when infected with the blight fungus, or of seed wheat, rye, etc., infected with the scab and other fungi to apply any seed treatment which would destroy the infecting fungus without destroying the vitality of the seed grain. In general we may say that where the seed infection or fungus spores, etc., are external to the visible or germinable grain, seed disinfection through treatment is possible, but for the internal fungi it is rarely possible. The loose smut of wheat may be amenable to special seed treatment with only partial loss of vitality in the seed wheat.

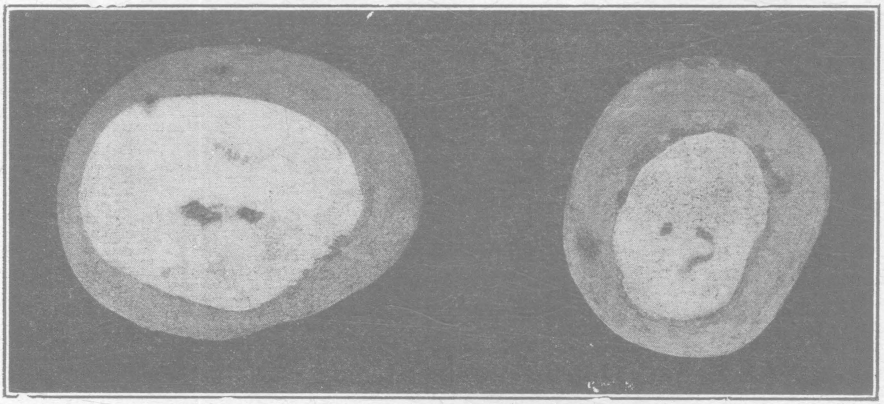


Fig. 18. Potato tubers attacked by Dry Rot Fusarium, showing sections near the stem-end of infected potato tubers. This infection may be easily discovered by cross sections made with a sharp knife, and sections from sterilized tubers gives cultures in Petri dishes. At times the discolorations extend to the middle of the tuber. (From a photograph by T. F. Manns).

METHODS OF SEED TREATMENT

The methods of seed treatment heretofore employed are set forth in the spray calendar and consist in an immersion of the seed in hot water of definite temperatures or in solutions of formaldehyde of different strengths. The formaldehyde solutions may also be employed to sprinkle piles of seed grain and in this manner less handling of the grain is required. More recently it has been proposed to disinfect seed potatoes, onions, forage, etc., through fumigation with formaldehyde gas liberated by boiling the solution, or better by mixing formaldehyde or formalin solutions with pulverized potassium permanganate by which the gas is liberated.

With seeds, tubers, roots, bulbs, etc., the limitations of the treatment are not so narrow and these may be immersed for longer or shorter periods in solutions of corrosive sublimate, formaldehyde, etc., or they may be exposed to fumigation with gaseous formaldehyde as has just been stated. (See Seed and Soil Treatment, pages 344 and 345 following.

SOIL INFESTING PARASITES IN FIELD AND FORCING HOUSE

The cultivated soil is a medium in which many species of bacteria and fungi survive from year to year. The public is familiar with the doctrine of bacterial infection or inoculation of the soil in its relation to the nodules or tubercles of clover, alfalfa, soy beans, cowpeas and other cultivated plants of the Family of *Leguminosae*. One form of bacterium is not sufficient for both clover and alfalfa. This flora of the soil both in relation to bacteria and fungi of considerable range of species, is enriched by the applications of manure and by the practices of culture; by this is meant that the growing of a given crop a second time or a third time consecutively in the soil increases the probability that the plant roots remaining in the soil are carried over from one crop to the next together with root parasites which cause disease in the plants of this crop. Manifestly, likewise, if in preparation for a given crop to be grown for the first time upon the land, rather liberal applications are made of fresh stable manure containing spores or mycelium, more especially the resting forms of mycelium called sclerotia, the soil will become infected by this manurial application. While this source of infection is rather rare in field culture we have specific examples as in the scab disease of potatoes transmitted in this way; the scab of sugar beets may be carried in like manner. But in forcinghouse culture where heavy applications of manure are made, the chances are greatly increased that soil infecion will be produced from the manure.

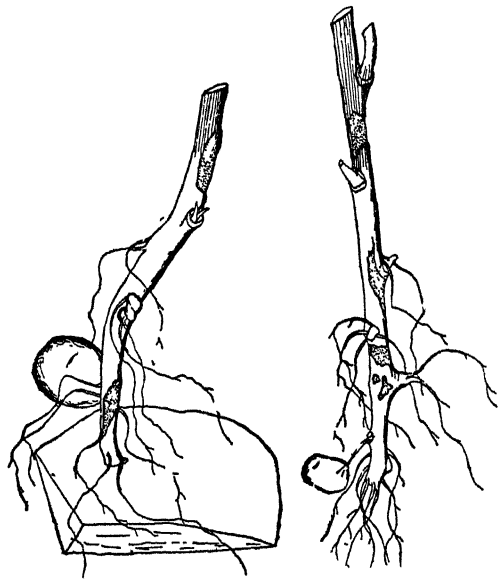


Fig. 19. Bases of potato stems (Carman No. 3) collected June 7, 1902, Cheshire Ohio, showing injuries by Rhizoctonia. The shaded areas are darker lesions occupied by an abundence of Rhizoctonia hyphae; the tops showed conspicuous Rosette effects. Reduced from Bulletin No. 139.

It is of value to remember that seed infesting or seed infecting organisms are also very largely capable of survival in the soil nidus of cultivated soils, thus our troubles multiply adequately if our care be inadequate to avoid them.

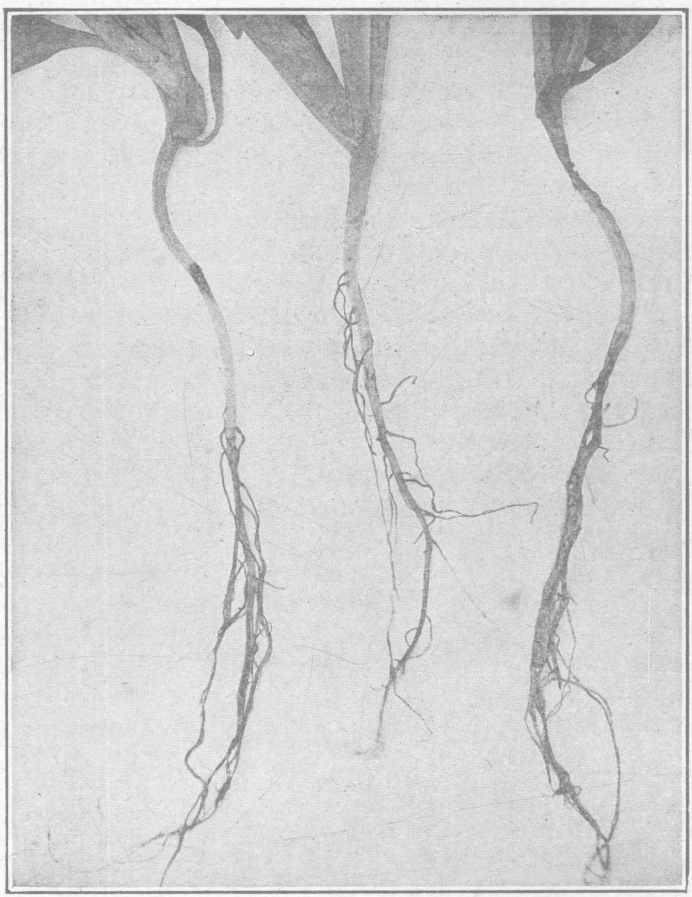


Fig. 20. This shows root portions of seedling lettuce plants with dark spots, lesions, caused by attacks of the rosette fungus, *Rhizoctonia*. With the younger plants these attacks cause large mortality and in very small seedlings the stem of plantlet may early collapse after the manner shown in rotting specimens. (From Circular No. 57).

THE AVOIDANCE AND PREVENTION OF SOIL INFESTING DISEASES

We, perhaps, may assert that the law of nature is that of a diversified plant covering; at any rate the law of successful culture will permit of statement in terms of crop rotation. And it is true that as culture ages the number and seriousness of plant diseases increase almost in geometric ratio. It is further conspicuously true with respect to those areas devoted largely to continuous culture in a single crop or in a group of closely related crops such as the growing of wheat in Western United States and Canada, also in the growing of flax and other crops. Potato growing in San Joaquin county, California, illustrates this danger. Muck lands devoted to vegetable culture, tempt the grower to continue his crops of celery, onions, etc. Here we have as a true result the accumulation of diseases which attack these plants; thus for field culture we are constantly facing these problems of soil infesting diseases and the handling of the diseases is not an easy problem since change to rotation may mean

a serious decrease in the return from the crop on the special type of soil. While for general field culture avoidance of conditions may be successful, this is by no means a simple matter. Rotation is often absolutely necessary, but this same rotation will not rid the soil of the onion smut fungus, nor of some other parasites such as in the case of the club-root fungus of cabbage and related plants. In these cases some soil treatment must be applied to field areas. In the case of the onion smut it is sufficient to apply a formalin drip which will fall with the seed and disinfect the soil layer in proximity to the seed. This is effective because the smut fungus can penetrate the germinating onion plant only in the earlier stages of growth. On the other hand with cabbage club-root, where plants are transplanted from the beds in which they are grown, some general method of soil treatment which involves the soil mass is more effective. In this case it is the application of stone lime or caustic lime in liberal quantities. These examples are only illustrative of general conditions to be met with. In the case of potato scab, it is found necessary both to disinfect the seed where scab is present, even to a limited extent, and to plant upon new soil not infested with the scab organism. Potato rosette is certainly an acid loving parasite.

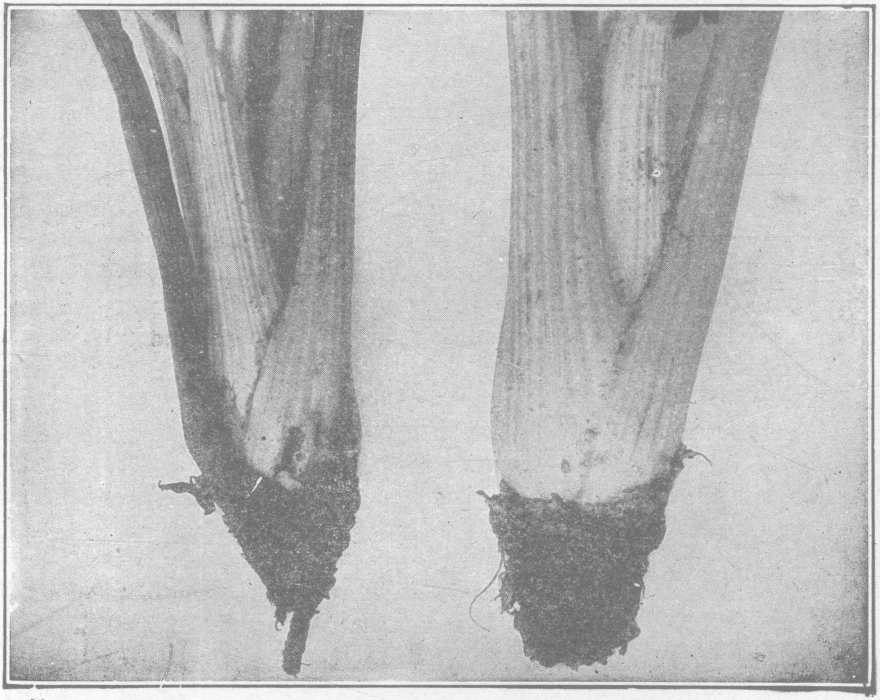


Fig. 21. Lower portion of two cabbage plants showing effects of root rot, *Rhizoctonia*. It will be observed that nearly all the roots of the plants have rotted off in consequence of the attack. (From Circular No. 72).

Under the diseases described for each plant, methods of avoidance and treatment are indicated and the diligent student will find other instances of similar character mentioned therein.

SOIL TREATMENT IN THE FORCING HOUSE

About our great centers of population have grown up conspicuous developments of the forcing house industry; large areas are covered with glass and these hothouses are maintained at the necessary temperatures for the production of the special green crops found profitable, At the same time the soil of the hothouse beds is very liberally manured and enriched further by applications of commercial fertilizers. Not only do these applications of manure tend to enrich the flora of the soil and to introduce particular root parasites, but the decay of the organic matter of the manure also tends to produce humus acids in considerable quantities. Along with these are brought parasitic eelworms which are peculiarly fatal to curcurbitaceous plants, to violets and to some other hothouse crops. Next to the eelworms the most conspicuous organism in our area is the sterile fungus Rhizoctonia, whose resting forms or sclerotia may be readily introduced in manure. To meet this indoor soil infection, special methods of soil sterilization had to be developed, since soil rotation is practically impossible in the forcing house.

These methods of treatment are in brief, steaming of the soil to render it practically sterile, so far as these parasites are concerned, and a method of formalin drenching. This method of steaming is ideal, or almost so, in its results upon sandy or loamy soils, but often entails unfavorable changes in heavy silty or clay soils. Essentially, it consists in burying a series of perforated pipes in the soil at intervals, covering the surface of the beds and passing live steam in sufficient volume into the pipes. These pipes are prepared in sets with cross heads and boiler connections and are perforated at desired distances. The surface of the bed is covered with canvas and the steam passed into the system for such period as is required to heat the soil to a temperature from 180° to 212° Fahr., to be maintained for one hour or more. This applies to high pressure boilers; for low pressure or hot water heating systems where the steam is applied in subdrains, four to five hours steaming will be required with a pressure of six to seven pounds. This treatment is effective for destruction of the eelworms or nematodes of cucumbers, violets and lettuce, the rot or drop fungus of lettuce, the rosette fungus, and in general of all soil infesting parasites.

Another method, the formaldehyde or formalin drench, has proved successful for the control of *Rhizoctonia* in greenhouse soils. This consists in a solution of 40 percent formaldehyde in water, say at the rate of two to four pounds in 50 gallons of water. This is applied at the rate of one gallon per square foot of area and will involve a very severe wetting down of the bed and prevent immediate resetting of the soil owing to the persistence of the formaldehyde. One secondary effect of formaldehyde drench and lime in sandy soils in the forcing house was an increased yield of lettuce amounting from 60 to 90 percent over the ordinary crop. This was explained on the assumption that the parasitic fungus was destroyed and certain other inhibiting organisms at the same time.

THE BEST FORCING HOUSE PRACTICE

The best forcing house practice will contemplate a recurrent disinfection or sterilization of the soil during the idle period; it should be preceded by whatever applications of limestone and manure that are to be made to the soil, then after thorough working and application of water to correct unevenness of moisture the soil may be sterilized by steam, or the formaldehyde drench be applied with assurance of results: obviously also this treatment must extend most vigorously to the plant beds and bring healthy seedlings to soil in which the soil parasites have been destroyed.

The following tables of seed and soil treatments taken from the spray calendar will be of more use than extended description or discussion:

SEED AND SOIL TREATMENTS

SEED OR PLANT	FOR WHAT TREATED	TREATMENT	METHOD OF TREATMENT
Barley	Smuts	Formaldehyde or modified hot water	Sprinkling with stronger formaldehyde as for oats is successful. Soak seed enclosed in sacks four hours in cold water, let stand wet four hours more and dip five minutes in hot water at 130 degrees Fahr., or three degrees lower than for other hot water treatments.
Bean	Anthracnose	(See spray calendar)	
	Weevil	Bisulfid of carbon	Submit to fumes for twenty-four hours in air-tight vessel or chamber.
Begonia	Nematodes	Sterilize soil with steam	Disinfect soil to be used by heating with steam as described under cucumbers.
Cabbage and Cauliflower	Club-root	Quicklime on soil	Apply stone lime (quicklime) preferably ground lime, before planting, at rate of 80 bushels per acre and work into the soil with suitable tools.
	Maggot	Bisulfid of carbon or tobacco dust	Make hole in soil near root, pour in about a teaspoonful of bisulfid of carbon and fill holes with soil. Cover soil around stalks freely with tobacco dust once per week.
	Nematodes in hothouse	Sterilize soil with steam	See next.
Cucumber	Nematodes in hothouse	Sterilize soil with steam	Sterilize soil with steam by perforated pipes, high pressure, 1 to 2 hours, or low pressure in subdrains 4 to 5 hours.
	Root-rot	Drench soil with formaldehyde or sterilize as above	Drench soil with formaldehyde 3 to 4 lbs. to 50 gallons of water preceding lettuce crop.
Lettuce	Rosette	Sterilize soil with steam or drench with formaldehyde	Steam as above or drench with formaldehyde 1½ to 2 lbs. where trouble follows with cucumbers use 3 to 4 lbs. to 50 gals. of water, 1 gal. solution to each sq. ft. of surface. Two weeks must elapse before setting plants.
	Rot	Steam soil	
Oats	Anthracnose	Formaldehyde	Treat seed as stated in next to kill adhering spores. This is only a partial remedy.
	Loose smut	Sprinkle seed with formaldehyde or immerse seed in hot water. Soak seed in potas. sulfid...	Preferably sprinkle a pile of seed with shoveling to saturate with formaldehyde solution, one gallon to bushel, at three or four sprinklings; after three or four hours or over night in the pile, spread to dry. Immerse seed contained in open vessel for ten minutes in hot water at 132-3 degrees Fahr., for seven minutes at 136 degrees Fahr., or for five minutes at 140-2 degrees Fahr., spread at once to dry. Soak seed in ¾ percent solution potassium sulfid for 24 hours with stirring, then dry.
	Insects in stored grain	(See wheat)	
Onion	Smudge	Use formaldehyde as for onion smut	Sow seed with formaldehyde as for onion smut; rotate onions with other crops.
	Smut	Use formaldehyde or ground quicklime. Plant other crop. Use sets or transplanted seedlings.	Use formaldehyde solution 1 lb. to 30 gals. of water sprinkled on seed in contact with soil and cover at once, or better sow with drill and drip attachment, the solution falling with the seed. Or apply ground quicklime at the rate of seventy-five to one hundred and twenty-five bushels per acre just previous to seeding on freshly plowed land, and stir into soil. (See Bulletin 131).

SEED AND SOIL TREATMENTS Concluded

SEED OR PLANT	FOR WHAT TREATED	TREATMENT	METHOD OF TREATMENT
Onion	Storage-rots	Disinfect with formaldehyde gas	Fumigate to disinfect the dry onions, with formaldehyde gas in enclosed piles of slat crates for a period of 24 to 48 hours. (See description of method under fungicides).
Pea	Anthracnose (Blight)	Spray the growing crop with Bordeaux	Keep down infection of seed through spraying of plants. See Spray Calendar.
Potato	Scab	Soak uncut seed in formaldehyde or corrosive sublimate	Soak seed for two hours in formaldehyde or one hour in corrosive sublimate; then dry and plant on scab-free soil; formaldehyde gas may be used.
	Rosette (Rhizoctonia)	Soak seed in formaldehyde as for scab	Soak seed in formaldehyde as for scab; on infected soil use formaldehyde after manner in onion smut. (See Bulletin 145).
Roses	Nematodes in hothouse	Sterilize soil with steam	Heat soil with steam as described above; thoroughly disintegrated soil from sod one year or more old is less dangerous. Lime water stimulates affected plants but is not a remedy.
Rye	Anthracnose	Formaldehyde	Treat seed as for oats and wheat to kill spores. Remedy only partial.
Sweet Potato	Black-rot and Stem-rot	Formaldehyde	Soak or fumigate seed roots as for potato scab; discard old diseased hotbeds; drench slightly diseased beds with formaldehyde as for lettuce and tobacco. Then set plants on new soil.
Tobacco	Root-rot and Bed-rot	Drench beds with formaldehyde or sterilize with steam	Drench beds in fall or early spring with formaldehyde 2 lbs. or more to 50 gals. water, 1 gal. to each sq. ft. Do not seed until smell of formaldehyde has disappeared.
Tomato	Nematodes in hothouse	Sterilize soil with steam	As for roses and cucumbers above.
	Point-rot in hothouse	Mulch or sub-water	An insufficient water supply seems favorable to development of point-rot of green tomatoes.
Turnip	Club-root	Quicklime in soil	As for cabbage and cauliflower. Avoid succession of these crops.
Violet	Nematodes in hothouse	Heat soil with steam	The time for prevention is by soil treatment beforehand as for cucumbers above.
Wheat	Anthracnose	Formaldehyde	Sprinkling as for stinking smut may prove partial remedy.
	Loose smut	Modified hot water	Soak seed four hours in cold water, let stand four hours more in wet sacks, immerse five minutes in water at 133 degrees Fahr. and dry.
	Stinking smut	Formaldehyde, hot water or copper sulfate	Sprinkle grain in piles with formaldehyde as for oat smut, 1 gal. or less per bushel and dry in same manner. Dip skimmed seed for ten minutes in hot water at 133 degrees Fahr. and dry on disinfected surface or immerse ten minutes in solution of blue vitriol (copper sulfate); dry with air-slaked lime by shoveling. Use two pounds of blue vitriol to ten gallons of water. Grain may be sprinked in piles with copper sulfate or formaldehyde as for oats. (See Bulletin 97).
	Insects in stored grain	Bisulfid of carbon	Place one pound of bisulfid of carbon for each 2,000 pounds of grain in bins. Cover surface with blanket to hold the fumes which will spread through the mass, killing all insect life. Use in tight bins or buildings and do not use near fire of any description.

ROOT DISEASES AND ROOT-ROT FUNGI OF ORCHARDS

Diseases upon the roots of herbaceous plants are very commonly due to soil infesting parasites. As explained under that topic, the soil conditions may be favorable to certain parasitic organisms or without being especially suited to them soils become infested with fungi which tend to remain indefinitely and become a source of loss in crops and effort. See lettuce rosette, tobacco root-rot, potato dry-rot and root-rot of violet.

The root-rots of woody growths are commonly more or less truly wood invading fungi of the semi-parasitic type and become of interest to foresters as well as orchardists. A partial exception to this wood-invading character of these root-rot fungi is found in a recently discovered development of the tobacco and violet root-rot fungus, *Thielavia basicola* Zopf., upon catalpa seedlings in nursery. However, since even tree seedlings in their early stages have not developed their woody tissues to any great extent, they are susceptible to the same root parasites as are found on herbs. This will likely explain cases like that cited on catalpa and the trouble may pass as the seedlings become older. Yet it must be confessed that this still raises a question as to the effect of the general parasitism of even Thielavia upon the rootlets of trees like catalpa.

In forest woodlots, root-rots are likely to become of increasing effect. Wherever these tend to limit the reproduction of certain species in the woodlot, they will be injurious. In this respect they may prove an added reason for the rotation of conifers with deciduous growths. In coppice or cut-over lands such as prevail in the charcoal furnace districts of Ohio, the roots and stumps of the parent stem must be an eventual menace to the new growths which spring up about them. The exposure to the wood fungi which become timber or heart-rot sorts will be very great in all such cases. The gradual invasion of the new growths must often occur when these approach a size that gives a considerable heartwood cylinder. These are the great sources of trouble in coppice reproduction of timber trees.

Root-rots in orchard plantings are known more especially when these are made following oak and other species somewhat after the manner of coppice conditions. The rhizomorphic development of these root-rots is difficult to determine but is usually referred to *Agaricus melleus* (*Armillaria mellea*). See root-rots of apple, peach, etc.

An especial feature to be noted in root-rots of all sorts are the soil conditions as to excess moisture and aeration of the soil. In silty or clay soils of close texture and coagulable nature, with excess moisture, serious conditions arise. Any traces of root-rot fungus

under such conditions will involve increased risks. The necessity for drainage will usually be apparent and due consideration of the limits of certain orchard trees needs also to be given. Cherry trees and even peach and apple trees will not survive under moisture conditions wherein plum and pear trees may grow with profit.

Orchard replants in "clinker" locations wherein failures have been numerous, will raise these questions of root-rots and relative adaptability of different orchard trees. Rotation planting, as pear or plum after apple, plum after cherry, etc., may at times succeed and replace unsightly gaps in the orchard by flourishing trees of another sort. At present, drainage and aeration are our known methods of restricting root-rots under out-door conditions.

PARASITIC FOLIAGE DISEASES

Foliage diseases of every sort are caused by oxygen loving or aerobic species of parasites, and very often this development on the leaves consists of the imperfect forms of the fungus life history. These forms are none the less aggressive and injurious for this reason, but the exact manner of survival from year to year becomes important wherever not known. The application of this to preventive measures in the control of these diseases upon foliage and fruit is seen in the case of apple scab, the monilia rot of plums, peaches, cherries, etc., and in apple bitter-rot. These last two rot troubles survive in the "mummy" or dry rotted fruits and this explains the reason for the oft repeated injunction to destroy all "mummies" in addition to spraying operations. The bitter-rot of apples is propagated by means of summer branch cankers on the tree, as brought out in recent years. Other leaf forms survive on the fallen leaves or possibly in bud scales as with the leaf curl and "bladders" of the *Exoascae*. A large number must live over on the branches.

Parasites upon foliage soon become apparent from the spots on the leaves and dropping of fruit resulting. This dropping may come as a result of impaired vigor by reason of disease—then it is later, but is more often the direct result of parasitic attack by the disease upon the young fruits. Herein as elsewhere the philosophy of fungicides comes to our relief. A good foliage fungicide is a relatively insoluble compound which will not greatly injure the leaves with which it is in contact. The remedies for foliage troubles are applied in *anticipation of attack* and for the purpose of checking the fungus when it may appear. The relative efficiencies of various fungicides in early summer will possibly depend upon the sticking qualities of the sprays.

Foliage diseases, moreover, are liable to recur each year and this is an added reason for anticipatory treatments to ward them off. *Foliage diseases may not be neglected with impunity since the leaf is the plant's vital working organ and the plant must suffer from its impairment.*

BITING AND SUCKING INSECTS AND LEAF DISEASES

The part played by insects which wound the leaf epidermis, in the spread of leaf diseases, is often very important. Such wounding of the leaf or green stem whether by insects such as flea beetles, foliage eating worms, or by sucking insects such as mites, leaf hoppers and plant lice, opens the way for the spores of parasitic fungi or of bacteria or mere molds, any one of which may be injurious to the leaf. The early blight disease of potatoes is a good example. In seasons when there are many of these little black flea-beetles to puncture the leaves, the thorough control of both these insects and the early blight, *Alternaria* fungus, is called for. Many fungi of doubtful penetrating powers are truly injurious when they follow insect punctures of the leaves. Fortunately both these are secured by Bordeaux sprays. The reasons for such applications are of double character since they are to combat both the insect and the fungus to follow it.

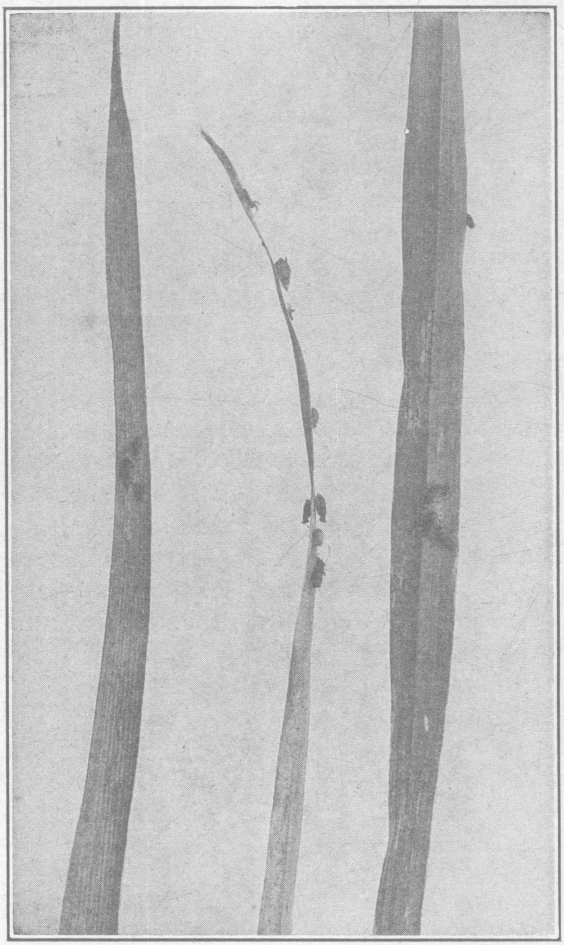


Fig. 22. Showing sections of blades of oats attacked by green lice (aphides). The right hand specimen shows type of injury resulting from the sucking of the aphis. In case these lice are carrying the organisms of oat blade blight, this sucking will lead to infection by the disease. (From a photograph by T. F. Manns).

With shade trees the leaf hoppers and mites may be so numerous that tip-burn and various leaf dying results from the injuries or punctures they inflict.

A more startling relation is that of the blade blight of oats, a recently investigated bacterial trouble. This bacterium is distributed and inoculated very obviously by the aphids or green flies (plant lice), and other sucking insects which prevailed during the seasons of 1907 and 1908 upon oats almost throughout Ohio. For fuller details see Blade Blight under Oats, and Bulletin 210.

Fig. 23. Maple shade tree, Wooster, with large branch cut off. Below this cut the wound fungus, (*Volvaria bombycina*) has developed and fruited; the cap is nine inches across. This shade tree was further wounded by wrappings of wire to stiffen a telephone pole. (From a photograph by J. M. Goheen).

WOUNDS AND WOUND INFECTION

With woody growths, especially in trees which attain considerable size, we have the various phenomena of disease infection through wounds; this infection later becoming evident by reason of decays set up in the woody tissues. Of course, in instances such as the bark disease of the chestnut, *Diaporthe parasitica* Murr., the disease may penetrate the living tissues. Not so, generally, in wounds of woody plants. Any large woody growth, as in forest or shade trees and in larger fruit trees, shows the combination of an external or living sapwood layer and an internal dead or heartwood cylinder. The commoner forms of wound infections are attributable to those species of fungi which cause decay of this dead heartwood. Among these are the long list of saprophytic, agarics, polypores and stereums. Because of the fact that this heartwood cylinder is dead, these saprophytic species of fungi, once they gain entrance into it, flourish there and invade the wood to a very great extent, even by adaptation to parasitic habit extending their work into the living parts causing death. The removal of a large branch of a shade tree or a fruit tree, unless the wound thus

formed is properly protected by dressing, opens the way for spores of these fungi which cause timber decay to obtain a start and thus eventually to invade the heartwood of the interior. For dressing cut off branches, asphaltum is admirable; in its lack gas tar is good, and either is better than ordinary paints.

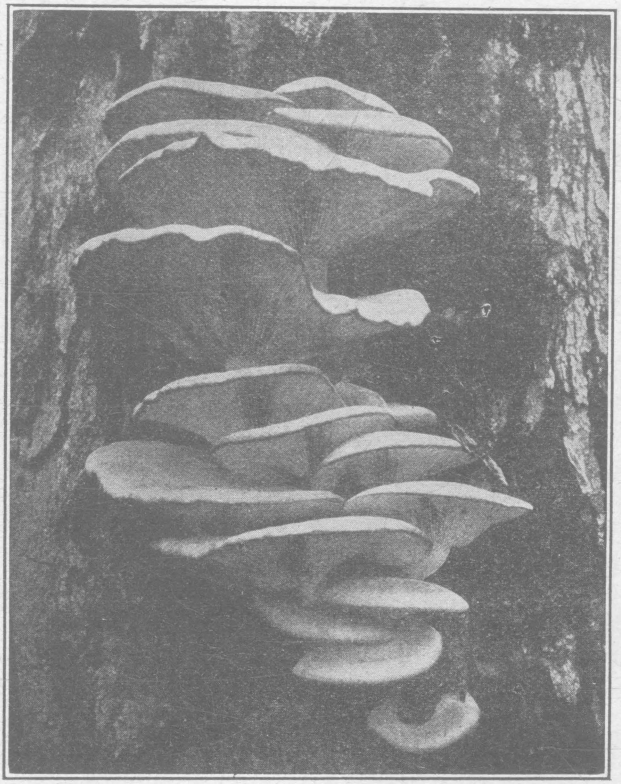


Fig. 24. A wound parasite (*Pleurotus ulmarius*) on the trunk of a maple tree. (After Freeman, Minnesota Plant Diseases).

There is always to be borne in mind that the protection of the woody cylinder of trees depends on its being covered by the living layer of sap wood. Every branch of considerable size connects directly with the extensive heart cylinder; we thus see that the wound fungi which attack the heart wood are the timber decays and their presence emphasizes the need for care in providing protection for all wounds, especially those caused by pruning.

Any decay becoming established in the dead heartwood may extend for long distances through this dead wood and in the end so destroy it as to be in a position to invade the external or sapwood layer.

In addition to the exposure of the internal woody cylinder to these decays, we have sap-rots due to various species of fungi which belong on the border line between the parasitic and saprophytic sorts: Among them are species of Fomes, Polyporus, Lenzites, etc. Any wound of the sapwood even though it does not reach to the dark heartwood, exposes to the danger of this infection, and with infection, to all the consequences of sapwood decay and premature death of the tree. These decays and those of heartwood are in line with those of the rots of structural timbers, but we are at this time interested only in their effects on the parts of the living plants.

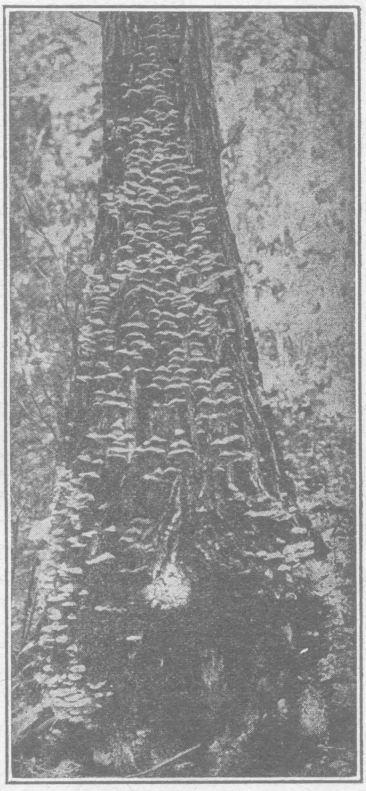


Fig. 25. Another wound parasite (a species of *Stereum*). The fungus obtained entrance in the wound at the base of the tree (an oak), and as shown by the fungus fruiting bodies, is gradually progressing upward. This tree died about a year after the photograph was taken. (After Freeman).

TIMBER ROTS AND TIMBER PRESERVATION

The decay of dead logs, wooden frameworks, or other structural timbers is caused by the attacks of saprophytic fungi belonging to the gill and pore fungi mentioned under wounds; these are of the great class of basidium bearing fungi, to which the fleshy forms, everywhere more or less abundant, belong. The most of them are included in the "mushrooms," which there is a strong impulse now to study and illustrate by photographs. These timbers are dead and are subjected to invasion by timber infecting species wherever the conditions as to air and moisture are such as to favor their development. Dry timbers are not subject to such attack because lacking the requisite moisture for the organism. Floors and other timbers of houses adjacent to the earth or to unheated cellars are often attacked by rot-causing species. The timbers of trestles, railway ties and the bases of fence, telephone and telegraph posts, where inserted into the earth or in contact with it, are kept sufficiently moist to invite attacks of this sort.

Wood that has been invaded by such fungi is reduced to the state called punk: that is, the wood fibers and arrangement in vessels to which the timber owes its strength, are broken down by the invasion of the fungus which flourishes at the expense of this woody tissue. There is no help for timber after it has once been attacked by rot fungi. Whatever preventive measures are taken must precede the attack. The most effective means of timber preservation is to cause it to be injected or permeated with creosote or other antiseptics. This is done by placing the timbers in vats containing the solution and extracting the air from the timbers so far as possible. The permanence of the effects of such timber treatment depends upon the resistance offered by the material used to gradual solution by water. In the case of creosote the results are quite satisfactory; with chlorid of zinc, subsequent solution takes place too readily, while with crude petroleum there is a tendency toward the evaporation of this substance when injected. The increasing cost of timber will stimulate timber treatments by making treatment profitable. One drawback at present is the necessity to import creosote for use in such work; possibly refiinery by-products from petroleum of a character analogous to asphaltum may find application in timber treatment.

Fig. 26. Fruiting bodies of the fatty Pholiota (*Pholiota adiposa*), in a wound of an oak tree trunk. (After Freeman).

ATMOSPHERIC CONDITIONS AS AFFECTING PLANT DISEASES

The relation between weather and the prevalence of certain plant diseases has been often recorded. The diseases which prevail are none the less parasitic, the difference exists solely in the temperature and moisture conditions of the atmosphere. Here we must distinguish clearly between the *cause* of the diseases and the *conditions* which favor the given diseases.

Certain parasitic fungi develop more rapidly under cooler conditions than the normal or average while others are favored by higher temperatures; all fungi are favored by large amounts of moisture when these stop short of water immersion and shutting out the needed air. In temperature we have an optimum which usually lies within certain maximum and minimum limits for any given species, but this temperature optimum varies with the organism; it is a matter which admits of exact determination for any organism. As to moisture, an abundant supply of water is the optimum for most fungi with which we deal in plant disease investigations.

In these atmospheric conditions of temperature and moisture the seasons of the year, in our climate, vary one with another. The seasons of heavy rainfall are commonly those of low temperatures by reason of the check on temperatures exerted by evaporation. Further, our weather service records show a tendency for our seasons to come in groups of cooler alternating with groups of warmer seasons; that is, we may have several years as with 1904 to 1907 (excepting parts of 1906) in which the mean monthly temperatures of those months which affect crops were decidedly below the normal or average. Evidently this normal lying as it does between the extremes, is surpassed by the warmer seasons which are said to be above normal. We have likewise, other alternating groups of years in which the season's temperatures are decidedly above the normal.

The effects of these cool seasons upon diseases are most clearly shown in outbreaks of leaf-curl of the peach and plum bladders in early season, and of potato late blight and rot, *Phytophthora infestans*, upon the potato crop. It is understood that plenty of moisture is the usual accompaniment of a cool season; from the combined effect of this supply of moisture and cool weather we have outbreaks of the potato disease even in northern Ohio where it does not appear certainly to survive from year to year. Such groups of cool seasons culminate as a rule in particularly injurious outbreaks of the potato Phytophthora with us; in more northerly situations, the disease is present nearly every season, but the outbreaks culminate with favorable weather conditions of excessive rains and lowered temperatures.

Stress has been laid upon the downy mildew of potato and cucumber respectively. It must not be inferred that other diseases do not offer like contrasts between dry, hot seasons and those of heavy precipitation and low temperatures accompanied by relatively high atmospheric humidity. Mention has already been made of the greater prevalence of the shot-hole disease of the plum and leaf-spot of cherry, *Cylindrosporium padi*, in rainy seasons over drier ones. The same facts will apply with respect to practically all external parasites of plants as in the scab fungus on the apple, the rot of plum, cherry and peach, and to the countless number of foliage diseases with which we deal from year to year.

Contrasting with the potato Phytophthora is the allied disease of curcurbits, the downy mildew, *Plasmopara cubensis*, which appears to flourish during our hot seasons and to disappear during the cool ones where grouped as above described. The writer has suggested that this Plasmopara does not survive in our climate but is carried northward each year by its conidia alone; the extent of spread will thus be limited by the length of period favorable to it. This period must be one of relatively high temperatures since this parasite is more widely distributed near the tropics. All these instances only make more clear the intricacies of the mutual adaptations of parasite and host which have resulted from the long periods in which these dwell together.

MEAN SUMMER TEMPERATURES AND RAINFALL IN OHIO, 1883-1909

Year	Mean temperatures degrees Fahr.					Mean Rainfall, inches				
	May	June	July	August	Three months Mean	May	June	July	August	3 Mos. Total inches
1883	58.0	69.0	72.1	68.2	69.8	5.72	4.25	4.16	1.88	10.29
1884	60.4	71.1	71.5	70.8	71.1	3.87	2.96	3.83	1.45	8.24
1885	59.5	67.1	75.2	68.9	70.4	3.97	4.34	3.20	6.33	13.87
1886	62.2	67.5	72.0	70.9	70.1	4.23	3.53	2.88	3.62	10.03
1887	66.0	71.0	77.9	77.9	75.6	2.87	3.85	2.16	2.39	8.40
1888	58.8	70.4	72.1	70.4	71.0	3.77	3.41	4.40	5.16	12.97
1889	60.2	66.7	72.5	69.1	69.4	3.71	4.13	4.25	1.50	9.88
1890	59.2	73.3	73.0	68.8	71.7	5.52	4.50	1.99	4.70	11.19
1891	58.0	71.0	69.0	70.0	70.0	2.20	4.82	3.82	3.07	11.71
1892	59.0	73.0	73.0	71.0	72.3	6.32	5.61	3.80	2.99	12.40
1893	58.3	70.6	74.5	70.7	71.9	4.97	3.34	2.49	2.17	8.00
1894	60.0	71.3	74.3	71.2	72.3	4.00	2.65	1.56	1.67	5.88
1895	61.1	72.0	71.6	73.5	72.4	1.80	2.47	2.00	2.96	7.43
1896	67.9	69.5	73.2	71.8	71.5	2.67	4.81	8.11	3.38	16.30
1897	56.3	68.1	75.5	69.4	71.0	3.93	2.85	4.65	2.72	10.22
1898	61.0	71.9	76.0	73.5	73.5	4.10	2.86	3.98	4.50	11.34
1899	63.3	71.5	74.1	73.7	73.1	4.32	2.96	4.18	1.82	8.96
1900	62.9	69.8	74.1	76.3	73.4	2.40	2.99	4.62	3.68	11.29
1901	59.0	70.9	78.1	73.1	74.0	3.69	4.38	2.73	3.32	10.43
1902	62.6	66.9	74.0	67.4	69.0	3.09	7.48	4.69	1.67	13.84
1903	63.9	64.4	72.9	70.7	69.3	2.82	3.97	3.67	3.20	10.84
1904	60.7	68.4	71.4	68.8	69.5	3.79	2.88	4.13	2.74	9.75
1905	60.7	69.2	73.0	71.7	71.3	5.63	4.72	3.93	4.46	13.11
1906	61.3	69.8	72.1	74.6	72.2	2.17	3.41	5.14	4.77	13.32
1907	54.5	65.6	72.6	69.5	69.2	3.47	4.57	5.36	2.48	12.41
1908	62.8	69.2	73.9	71.2	71.4	4.72	2.52	4.08	2.59	9.19
1909	58.7	70.1	*69.6	*70.3	70.0	4.72	5.86	*4.05	*5.21	5.04
Ohio, '83-'09	60.6	69.6	73.44	71.3	71.4	3.88	3.93	4.08	3.12	10.82

* Records Wooster only, not included in other than 1909 averages.

The blade blight of oats, a bacterial disease, has been found to be much influenced if not largely controlled by atmospheric conditions and perhaps more especially those of the earlier summer. These factors have been recently presented by a bulletin of this Department (See Bulletin 210). This publication contains a fuller table with respect to early summer atmospheric conditions. The development of the Fusarium blight and dry-rot fungus as a widespread and serious disease of potato plants causing premature dying and reduced yields is of interest here. The outbreaks in Europe seem to be associated with atmospheric conditions in spring and early summer. We need fuller studies on these inter-relations.

Insistence is here again made upon the observed relations between atmospheric conditions and parasitic diseases of plants that the grower may be stimulated to greater effort at close observation when the need exists and the student may be aided in his interpretation of the vast array of apparently inconsistent and complex facts by which he is to be instructed.

REMEDIES FOR PLANT DISEASES--FUNGICIDES

In no other line of applied science has America made more rapid progress than in the matter of plant disease remedies. While the general doctrine of parasitism and the transmission of parasitic diseases are thoroughly investigated and widely published in Europe, the application of remedies and the interest in disease prevention fall much behind the practices in America. Indeed, the writer's attention was in 1908-9 forcibly called to this matter by the statement of a prominent American Pathologist as to the relatively great advancement in America over the old world in this regard. Probably this greater progress is due to the greater readiness with which Americans engaged in crop production, accept the teachings of scientists and make practical applications of the results obtained.

Among remedies for plant diseases we must include all treatments which tend to restrict or prevent the recurrence of diseases, that is, all treatments which remedy infections or limit the spread of parasitic attack.

SEED AND SOIL TREATMENT

Seed and soil treatments naturally belong here; while somewhat full discussion has been given on pages 342-345, it is necessary to recall the measures employed in seed treatments as well as in soil disinfections. In the seed treatments high temperatures, as in the hot water, or the application of a germicide as in solutions of formaldehyde are applied to the seed grain to destroy adhering

spores. In the treatment of tubers and roots as the potato, etc., longer soakings with solution of formaldehyde or corrosive sublimate are required to kill not only external spores but resting forms of fungi such as sclerotia, etc.

With soil treatments we have the problem of killing out soil infesting organisms such as nematodes or eelworms and Rhizoctonia, Botrytis, lettuce drop, etc., among the fungi. All these results are obtained by thoroughly steaming the soil. In a measure the same results are also obtained from a formaldehyde drench as elsewhere described.

Fumigation for the destruction of seed infesting fungi or cutting infesting insects is of the same character and must be named here. The fumigation of nursery cuttings with hydro-cyanic gas is effective as is also the fumigation of stored grain with carbon bisulfid. We must also consider that wound coverings are methods of prevention in plant disease, since these coverings of asphaltum creosote, gas tar, paraffine and even of paint serve the purpose of excluding wound fungi which might otherwise cause serious decays. All these treatments that have just been enumerated apply to the treatment of the soil or of seeds and plants in resting condition. The great problem of keeping down infection during the growing period yet remains for the application of spray mixtures.

SPRAYING WITH FUNGICIDES--INSOLUBLE COPPER COMPOUNDS

The progress made in the control of plant diseases through sprays since Millardet's discovery of Bordeaux mixture (bouillon bordelaise) near Bordeaux, France, in 1883 shows how great was then and is still, the need for effective fungicides. The materials from which Bordeaux mixture is made consist of copper sulfate (blue vitriol) calcium oxid and hydroxid (caustic lime) and water. In the making of the mixture the copper sulfate is dissolved in water and should be diluted with a considerable amount of water; the lime is slaked or converted into lime putty from which a milk of lime is prepared. These two mixtures with the copper sulfate in aqueous solution and calcium hydroxid in suspension, mixed together make a chemical reaction by which the calcium in the lime displaces in part the copper in the copper sulfate, forming on one hand calcium sulfate or gypsum, and on the other the various combinations of lime with the metallic copper thus liberated. The actual reactions have been variously interpreted. More recent investigations show that several basic sulfates of copper and lime are produced. Whether any hydroxid of copper is produced has been questioned by Pickering, an English investigator. The light blue color is due to suspended

particles of these compounds which are evidently the effective agents in fungicidal action. These insoluble light blue copper compounds which, in this divided condition, are held in suspension in the liquid give it the characteristic color. The essential needs in making Bordeaux mixture are the presence of enough or even an excess of the base, calcium (lime), so that none of the copper will remain in soluble form as sulfate. This on the other hand involves the more or less complete change of the soluble copper into relatively insoluble, blue-colored copper compounds of another sort.

The philosophy of spray action is based first of all upon the absence of injurious effects from the lime products and from the copper compounds produced, when sprayed upon green foliage. In the second place, upon the effectiveness of these insoluble copper compounds through solution in the presence of moisture and carbon dioxid in the atmosphere, to destroy or prevent the growth and development of parasitic fungi. The time during which these insoluble copper compounds will be effective must depend upon the rate of growth in the plant parts and the adhesiveness of the application. The essential feature to be remembered is this; the insoluble or slowly soluble copper compounds become available by solution as needed. Where excess of fungicide is employed this has a certain danger upon apple or other foliage during showery weather and in all cases the strength is adapted to the host crop. Coincident with the spraying period there is frequent complaint of injury to apple foliage. Here we have solution effected more rapidly than is safe for the host; normally this risk is slight, but may be overcome by necessary modifications. Another matter is the amount, the number of gallons of the given fungicide to use; with more complete spraying appliances and high pressure of application, larger amounts and more complete covering of the parts are the rule. Recent results show that when the amount of copper in the mixture is near to the danger line these heavier applications increase the risk.

In the early translations from the French the strength of Bordeaux mixture was placed higher than is now the practice. For Ohio the following formula has been the rule for many years:

STANDARD BORDEAUX MIXTURE

Copper sulfate (blue vitriol)..... 4 pounds.
Caustic lime (unslaked)..... 4 pounds.
Water to make..... 50 gallons.

This is a 4-4-50 formula—a 2-2-50 formula is also used at times.

In making Bordeaux mixture, the copper sulfate may be dissolved in hot water (about 2 gallons) or better by suspending the sulfate contained in cheese-cloth sack, in a large vessel of cold water.

By using large quantities of both blue vitriol and water, say 50 pounds of copper sulfate and 50 gallons of water, a stock solution may be prepared, so that each gallon will contain one pound of the blue vitriol. In each case the solution of copper sulfate should be diluted say to one-half of tank capacity before admixture with the milk of lime.

The quicklime is slaked and then stirred to make milk of lime, adding water as needed to do this. The necessary amount of this milk of lime should be diluted to about 40 or 50 percent of the tank capacity and then run into a mixing tank with equal flow of corresponding volume of copper sulfate solution *before same is run into spray tank or barrel.*

All Bordeaux mixture formulae are useful as a vehicle in which arsenical sprays are added to serve as insecticides.

THE USE OF STICKERS IN SPRAY MIXTURES

Some experiments made in different parts of the country have shown beneficial results from the use of other materials added, such as sugar solution, soap, resin soap, etc., to increase the adhesiveness of the spray. In some spraying experiments by the Entomological Department of this Station, laundry soap was used effectively as a sticker to hold arsenical compounds in checking the berry worm or grape worm (See Circular No. 63).

The writer has proposed a modification of Bordeaux mixture which has been called "Bordeaux Mixture and Iron Sticker."

The following formula has been recommended:

BORDEAUX MIXTURE AND IRON STICKER

Copper sulfate (blue vitriol)	2 pounds.
Iron sulfate (copperas)	2-4 pounds.
Caustic lime	4-6 pounds.
Water to make	50 gallons.

In this spray the iron sulfate is added in order that it may be precipitated by the lime and serve as a more complete sticker than is provided by the standard Bordeaux mixture. It would appear possible by the weak solution as given for the copper compound and by this possible efficient sticker to make the reduced amount of the copper sulfate do the work as fungicide just as effectively and with less risk of foliage injury than with the standard Bordeaux mixture. The trials made up to this time upon apples in full foliage, upon grapes and upon potatoes indicate that the spray is efficient. *The iron sulfate is not considered a fungicide.*

SOLUBLE COPPER COMPOUNDS AS SPRAYS

Whenever it becomes necessary to continue spraying upon fruit as ripening approaches a more soluble copper compound than Bordeaux mixture must be employed or the spray will remain upon the fruit at marketing. The remaining spray, if excessive, injures the marketable character of the crop. Various sprays have been proposed for use at these critical times. The call for them has come in keeping down the black-rot on the grape and in the control of the several late season diseases of fruit, like the bitter-rot and black-rot of apple. The most satisfactory soluble copper sprays appear to be ammoniacal solution of copper carbonate or Soda Bordeaux mixture.

For the former the following formula is given:

AMMONIACAL SOLUTION OF COPPER CARBONATE

Copper carbonate..... 6 ounces.
Ammonia ..... about 3 pints.
(Enough to dissolve the copper carbonate and no more).
Water to make..... .... 50 gallons.

This is an effective spray made according to formula for the late applications upon grape and upon apple as maturity approaches. It is to be understood that this formula is not intended to make "eauceleste" which is a different preparation. No more than enough ammonia is added to convert the copper carbonate from insoluble to soluble form in the presence of water. A soluble salt of ammonia and copper is really produced. The proper times at which to make applications of fungicide as sprays has been carefully worked out in practice and directions are included in the spray calendars. There is a good reason in nearly every case for making the applications at the time recommended, since these sprays are timed to check the development of the parasite; if put on too long in advance the spray may be displaced, if put on too late the damage will occur without a possible means of prevention. All sprays as stated before are made in anticipation or in advance of actual danger from parasitic diseases.

SULFUR COMPOUNDS AS FUNGICIDES

Various preparations of the sulfids of alkalis and alkaline earths have been proposed as fungicides. A larger use has been made of the lime-sulfur formulae which have come into use largely for checking scale insects. These mixtures are made by boiling together caustic lime and flowers of sulfur in the presence of water. By this heating process a combination is effected between the calcium and the sulfur, and sulfids of various compositions are formed. For practical purposes the color reactions are used as a guide. This spray applied

in the dormant period or just as the buds are swelling is effective against the scale insects and is also efficient as a fungicide. The lime-sulfur has very largely displaced other fungicides against leaf-curl of the peach. More recently the self-boiled lime-sulfur formula has been proposed. It promises to be effective upon peach trees in foliage. This is a much more dilute formula than the one used upon dormant trees; both are described in the spray calendar. Latterly, various dilutions of the lime-sulfur residues formed when lime and sulfur are boiled together, have come into use as sprays for orchard use.

SOLUTIONS FOR SEED TREATMENTS AND DISINFECTION:

FORMALDEHYDE SOLUTIONS

Formaldehyde in 40 percent solution is obtained upon the market. Solutions of this 40 percent compound in water are effective in seed and soil treatments and for disinfection. The following are standard strengths:

For oats and wheat, 1 lb. or pint 40% formaldehyde to 40 or 50 gals. water.
For potato scab and rosette, ½ pint of formaldehyde to 15 gals. water.
For onion smut, 1 lb. of formaldehyde to 25 or 33½ gals. of water.
For soil drench, 2 to 4 lbs. of formaldehyde to 50 gals. of water.

CORROSIVE SUBLIMATE SOLUTION

For treatment of potato tubers and for laboratory disinfection, mercuric chlorid, corrosive sublimate, is used as follows:

Corrosive sublimate ..... 2 ounces.
Water ..... 15½ gallons.

GASEOUS DISINFECTION WITH FUNGICIDES

Latterly the methods used for the disinfection of houses wherein patients have suffered from contagious diseases such as diphtheria, scarlet fever, etc., have been extended to the treatment of plant diseases. The following formula of the Maine Board of Health is applicable to the details below given:

FORMALDEHYDE GAS

Commercial 40% formaldehyde ..... 3 pounds.
Potassium permanganate crystals ..... 23 ounces
Sufficient for 1000 cu. ft. of space occupied by crates or trays.

The following suggestions from the spray calendar of 1908 will be helpful to students or experimenters who have not access to other literature:

"Enclose open tiers or piles of slat crates filled with dry onions, potatoes, etc., in tight room or oiled tent of canvas buried in earth about the base. Generate the formaldehyde gas in a flat bottomed

dish or pan of adequate capacity by placing one of the materials, as the liquid formaldehyde, in the pan, and adding the other the last thing before retiring. Then close tight and allow to remain closed 24 to 48 hours.

Proportionate or multiple unit amounts may be taken for smaller or larger enclosed spaces. Applicable to fumigation of seed potatoes for scab, sweet potatoes for rot troubles and to newly gathered, dry onions before storing for winter.

For grain elevators to disinfect against conditions there or for mass treatment of seed oats and wheat a similar use is made of formaldehyde gas.

ROT DISEASE LOSSES IN STORAGE

No sharp line can be drawn between diseases of edible plant products which usually infect these crops previous to harvest, and the rots, molds or decays in such fruits and vegetables during storage. It has seemed best, for this reason, to insert here a brief discussion of these storage troubles which apply to products grown in our region. We can scarcely be called on to present the facts concerning the diseases of citrus fruits in storage or in transit.

All growers of fruits and vegetables in our state are liable, however, to have had losses from rots of fruits and vegetables during storage upon the farm. In the more recent custom of concentrating such storage products in cold storage plants, especially constructed for that purpose, the problem has only been transferred or transplanted: the difficulties have not been entirely overcome.

For the fruits known as perishable, namely, for peaches, plums, cherries and grapes, the custom of brief storage has become well established; the rots or other injuries, such as those that come from crushing, are well known. The storage rots are not different from those commonly found in the orchards—indeed, they are usually the common soft-rot of stone fruits, *Monilia fructigena*. Storage or transit losses from it are but an accentuation of orchard conditions. Also with the stone fruits, as a result of bruising and shipment, we have various of the common molds which develop on the bruised surfaces. The more usual ones are the common bread mold, *Mucor*, the blue mold, *Penicillium*, or the almost equally frequent form of green mold, *Aspergillus*. None of these, however, is likely to penetrate very deeply and be a serious enemy of these fruits. This arises, however, not so much out of the lack of ability to injure by these mold attacks, as from the very brief period of time which these tender skinned stone fruits are held before consumption. As has been pointed out by Powell and Smith, the

same common molds, including especially Penicillium, possibly with the aid of others, are sources of serious loss in the handling of citrus fruits—oranges, lemons, etc., during their prolonged periods of transit and storage.

In the case of grapes the losses are almost altogether due to breaking of the skin following which molds and bacteria are liable to appear under favorable conditions.

STORAGE ROTS OF APPLES AND PEARS

With apples the commonest storage rot for our district is doubtless also the commonest orchard rot, namely, black-rot, due to the black-rot fungus, *Sphaeropsis malorum* Berk. All are familiar with orchard conditions liable to prevail at ripening time. This fungus is generally found, especially in orchards of mixed varieties, because some sorts are commonly attacked by it. The same fungus causes cankers upon branches of the susceptible varieties and is usually well distributed over orchards. The punctures of worms or of bees, or wounds caused by mechanical injuries such as occur in wind-falls, and the various drops at picking time, afford easy entrance for the fungus. In consequence we must expect that the fruits which have been in any way punctured or injured, have also been exposed to infection by the black-rot fungus. Such infected fruits are very liable to rot because of the progress of the fungus, if conditions are favorable. The high temperatures of storage sheds and ordinary freight cars during October and early November in our climate, are such as favor its development.

In the light of our present knowledge the best we can do is to transfer fruit as soon as possible to storage where the temperatures are low enough to restrict the fungus. It follows without saying, that good results are obtained only from absolutely sound fruit, and the low temperatures of cold storage houses, 42 degrees or below, may be relied upon to check this rot to a very large extent, provided only sound fruits are placed in storage.

Naturally the discussion which follows under the storage of onions will raise the question here as to the practicability of gaseous disinfection of apples by the use of formaldehyde gas. It would seem possible under favorable weather conditions when fruit can be gathered dry and brought into storage houses in that condition, to disinfect the fruits by the formaldehyde gas method. Of course it follows that the period of disinfection will be brief in order that little or no gas will be absorbed by moist or exposed fruit surfaces, since formaldehyde is objectionable in foodstuffs. The time of fumigation may not need to be more than about half that used for potatoes or onions, and the strength of the formula may even be modified. The aim would be the destruction of external spores, etc., which certainly are a menace at all times.

The bitter-rot fungus, (*Glomerella rufomaculans* (Berk.) Von Schrenk) may also develop in storage apples where these have become attacked by it before harvest. The bitter-rot may be more common upon late summer and fall varieties in transit, than in ordinary winter storage. Certain sweet apples, such as Bentley Sweet, are very susceptible to bitter-rot losses in storage. Cold storage temperatures hold back the development of the fungus, but cannot disinfect the diseased fruits.

Pear rots with us are almost exclusively those which occur in the orchard. The leaf-spot fungus (*Entomosporium maculatum* Lev.) also attacks the fruits of pear and may become a source of loss in storage. This applies more particularly to inferior grades of fruit. Pacific coast fruit which is shipped to our district, may further suffer from some of the ordinary molds which find access to the fruit entirely through bruised or other injured areas.

The brief storage of quinces usually does not lead to much further development of the quince rot. The fungus in question is commonly the same as that in the apple rot, (*Sphaeropsis malorum* Berk.).

STORAGE ROTS OF POTATOES, ONIONS, ETC.

With vegetables we have a very wide range of storage troubles. In the case of potatoes we have two general types of rots, namely; wet-rot and dry-rot. The wet-rot of potatoes commonly results from two causes, viz.: The late blight or rot fungus (*Phytophthora infestans* D'By.) may be expected to cause considerable losses of the tubers in storage when these have been gathered from Phytophthora infested fields and bacteria may cause rot in injured tubers. In Ohio, as stated under this disease of potatoes, the late blight and rot fungus is not commonly prevalent. Perhaps little can be done to preserve the tubers from such fields except to market the crop promptly and to store with especial respect to the optimum conditions. The best temperatures for such potatoes will be warmer than for apples, and it is very desirable that moisture be kept as low as possible.

A wet-rot of potatoes, purely or very largely bacterial in cause, must also be dealt with. This rot bacterium is different from the bacterium of potato wilt, (*Bacillus solanacearum*) and without the latter may also induce considerable decay. It is believed the bacteria producing this wet-rot gain entrance through injuries to the tubers and that low humidity—dry storage—is especially desirable in keeping down losses from this source.

Dry-rot of potatoes is due to a fungus (*Fusarium oxysporum*) which appears to belong among our soil infesting fungi. This fungus appears to be the cause of premature dying of the potato plants and it certainly survives in the tubers from such infected plants. At harvest time, as shown under dry-rot of potato, tubers show infection at the stem end. Subsequently during storage the fungus penetrates more deeply into the tubers and will often produce dry-rot of the infected tubers. Further descriptive matter concerning dry rot will be found in the special part of the bulletin under potato. For storage of such infected tubers, as well as for the general crop, it is desirable that storage temperatures be kept about 42 degrees Fahr., or slightly lower.

Sweet potatoes also suffer from a large variety of rot troubles. These sweet potato rots are more or less special in character and since the crop is not largely handled in cold storage, nothing is here offered in addition to what appears in the special part of the bulletin

ONION ROTS IN STORAGE

Onion rots are a serious matter with onion growers and onion dealers as well. It has been found that particular varieties of onions in our climate are susceptible to special diseases. For this reason we must consider white onions such as White Silverskin, White King, etc., in a separate class from the rots of red and yellow onions such as the Globe and Wethersfield varieties.

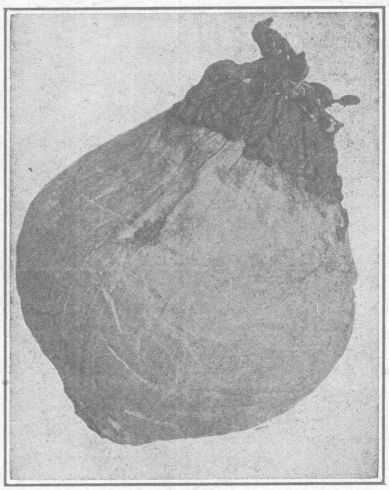


Fig. 27. A white onion that has been destroyed by a blackneck or dry-rot fungus, *Sclerotium cepivornm* Berk. This parasite has entered the onion through the green neck which was cut off at the time of harvesting the crop. (From a photograph by T. F. Manns).

With the white onions the problem is partly a field problem at harvest time, and partly one of storage. The growers are in the habit of gathering the white onions before the tops fall and topping them immediately, instead of throwing together in heaps for absorption of the substance of the tops by the onion bulbs as is practiced with the riper red and yellow varieties. After topping the white onions are placed in slatted crates, and these crates are stacked in the field or in open sheds where they are kept dry. Often the loss from rot during the six weeks following harvest may reach 60 percent of the

crop, and as shown by investigations in Connecticut and our own state, it has not always been clear why these losses are so large. Recent investigations by this department lead us to believe that the green onion neck of white onions handled in this way affords entrance for the organism of the rot.

The sclerotium rot (*Sclerotium cepivorum*) appears to be the most serious, although smudge or anthracnose of the onion (*Vermicularia circinans*) may sometimes cause large losses. Both these rots are described under diseases of the onion. The writer believes the Sclerotium rot is the larger criminal, and that both may be handled by disinfection of the onions immediately after harvest. This disinfection may be carried out as described under the Maine formula for Formaldehyde gas treatment, which is:

Commercial 40 percent Formaldehyde..... 3 pounds.
Potassium Permanganate crystals... . ... 23 ounces.
Sufficient for 1000 cu. ft. of space occupied by crates or trays. (See page 360).

The object of immediate disinfection is to prevent the entrance of these organisms, particularly the sclerotium rot, through the green neck of the newly topped onions. The exuding juices offer favorable culture conditions for the fungus to develop.

When no fumigation is practiced following harvest, the onions which are found to be sound and delivered for storage at the close of the season may very profitably be treated in this way before winter storage. Both these rots are essentially dry-rots of onions. In addition, sometimes, we have wet-rot of white onions which may be either due to bacteria or to the same fungus as the wet-rot of Globe or other onions mentioned below.

The rots of yellow and red onions are of both the wet-rot and dry-rot types, but the wet-rots are much more serious with these varieties. Doubtless, as in all vegetables held for a long time in storage, we have many cases of wet-rot in onions where some of the common decay bacteria are the chief cause. These find entrance through wounds, as in topping, and, under conditions favorable for their development invade the tissues of the onion and cause decay.

In addition however, to the wet-rots due to bacteria of undetermined species, we have a specific wet-rot of onions due to Fusarium species. This wet-rot fungus belongs to the same group as the potato dry-rot and is liable to infect soils in which onions are grown year after year. Rotted onions will show external developments of the pink fungus and may be detected in that way as well as by use of the microscope. The chief factors of control with onions of this kind, are in the methods of culture followed to produce the crop.

Dry-rot of red and yellow onions is rather rare and is commonly referable to the anthracnose or Vermicularia dry-rot fungus described under white onions. The best temperatures for onion storage are about 38 to 42 degrees.

SPECIAL PART II

DISEASES OF OHIO PLANTS. ARRANGED ALPHABETICALLY ACCORDING TO HOST PLANT

ALDER

Powdery Mildews. The alder suffers from several powdery mildew fungi on the leaves (*Phyllactinia suffulta* Sacc., *Erysiphe aggregata*, (Pk.) Farl., *Microsphaera alni* (DC.)Wint.) These retard development as with other leaf coverings. Alder may also suffer from two or three leaf infecting diseases such as an anthracnose and a leaf-spot. We have as yet little data concerning other occurrences owing to the neglect of the study.

Stem Blights. From England an interesting branch parasite (*Ditopella fusispora* De Not) has been reported by Plowright. This may or may not as yet occur with us.

Root Tubercles. These root developments on the alder and some other woody plants are commonly described as *Mycorhiza*. The particular organism (*Frankia alni* Wor.) has attracted a good deal of attention from students of forest problems in Europe. Investigations of such growths upon the roots of our woody plants is very much needed at this time in Ohio.

ALFALFA--LUCERN

Anthracnose. Two new anthracnoses have been discovered attacking alfalfa; the first of these, *Colletotrichum trifolii* B&E, so far as we know occurring exclusively on plants of this family, the other, *Colletotrichum* sp., occurring only on alfalfa in northern Ohio. The first one, which we may call clover anthracnose, was discovered in Tennessee and has appeared upon alfalfa as well as red clover in the southern portion of Ohio. It is less prevalent on alfalfa than upon the red clover. Up to this time this disease has not been discovered upon either host in the northern half of the state. The second anthracnose occurred recently upon alfalfa from Sandusky and Carroll counties and has not been described. Both of these diseaseses show as a specific lesion or diseased spot on the stem or leaf-stalk in the advanced stages of attack. Following this the plants wilt or die and are discovered in this way. The disease is too new with us to measure its injuries directly. To the writer it appears less serious than the dodders or the root-rot troubles.

Bacterial Blight (Yellowing). A bacterial blight of alfalfa, of which the causal organism has not been definitely determined, has been reported from Colorado where it appears to be spreading. In 1907 and to a still greater extent in 1908, there was much complaint of general yellowing of leaves of second crop alfalfa in Ohio and adjoining states, even extending to North Carolina. The symptoms were general yellowing of this crop. With brighter, drier weather later the next succeeding crop was of normal color. Bacteria have been found by the Assistant Botanist in connection with this trouble in specimens from eight localities and from four different counties in Ohio during 1908 and 1909.

Downy Mildew. The downy mildew fungus (*Peronospora trifoliorum* D'By) has occurred in Colorado, and is very liable to occur in our state. No suggestions can yet be made as to its prevention

Leaf-Spot Fungus. This forage plant is grown in parts of Ohio. It is attacked by the leaf-spot fungus (*Pseudopeziz medicaginis* (Lib.) Sacc.) which is found upon both leaves and stem. The small dark spots produced by it are easily seen. In

attempts to produce alfalfa seed at this Station, the fungus has stripped the leaves and seed capsules before maturity. It is very likely to prevent success in growing this seed in Ohio, though it is much less injurious to the forage crop proper because of cutting at short intervals.

Root-Rot. The same parasitic fungus (*Fusarium roseum* Lk.=*Gibberella Saubinetii* (Mont.) Sacc.) which attacks wheat in the form of scab and also red clover, has been found killing out alfalfa at Wooster (See Bulletin 203). This fungus may survive in stubble fields where wheat and oats have been grown. It readily kills off the young seedlings of alfalfa and if the soil is not fully prepared for alfalfa seedings, the root-rot may extend its work and further destroy the stand. At present nothing better is known than adequate dressings of lime, preferably raw limestone, for areas to be seeded, together with their proper enrichment. At this time warning is given as to the possible seriousness of this trouble in the future. While not specifically noted in America another root-rot fungus somewhat known on other crops (*Rhizoctonia*) has also been reported upon alfalfa from France. Another root-rot fungus (*Ozonium omnivorum* Shear) well known upon cotton, also attacks alfalfa in the southwest. I believe this is not known to occur in Ohio.

Rust. Alfalfa suffers from a rust fungus (*Uromyces striatus* Schroet) and while it may scarcely have appeared in Ohio, it is almost certain to do so in time. Like the similar leaf diseases of red clover, it may have rather small economic interest.

APPLE

Bitter-Rot or Anthracnose. In recent years this fungus (*Glomerella rufomaculans* (Berk.) Sp. and Von Schr.) has been investigated and its survival in the mummy fruits and cankered branches proved. (Bulletin 40 Virginia Experiment Station; Bulletin 77, Illinois Experiment Station; Bulletin 40, Bureau of Plant Industry). This bitter-rot is also a ripe-rot, in common with other anthracnoses. For Ohio certain varieties are the chief sufferers; one of these is the Bentley Sweet grown in Belmont county, another is the Rambo. The disease develops in the later season and it seriously impairs both the eating and keeping qualities. For its control the destruction of mummy fruits and attention to branch cankers are necessary in addition to the application of sprays. Since we know the life history of the fungus better it has been possible to control the bitter-rot successfully under orchard conditions as the annual sources of infection in mummy fruits and cankers have been mastered. In this late spraying soluble sprays are used toward the end as with the black-rot of the grape.

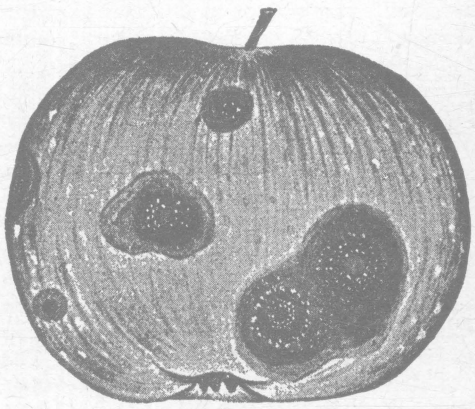


Fig. 29. An apple attacked by bitter-rot. A regular curved outline of the spores will be observed, the conidia of the fungus developing in concentric forms under suitable conditions. After Alwood.

Black-Rot. The black-rot also at times called brown-rot, is apparently more common in the orchards toward the southern portion of the state. The writer has found it a serious matter to control the black-rot fungus (*Sphaeropsis malorum*

Pk.,) which attacks both fruit and branches and is a bar to successful maturity of Northern Spy, Smith's Cider and some other varieties at certain times. It also invades storage apples and this rot is the most universal one in ordinary cellar storage. With varieties adapted to climatic conditions, methods of handling by sprays and destruction of cankers and mummy fruits should prove as effective as with bitter-rot. Unfortunately the varieties which most commonly suffer from black-rot are those growing beyond their safe range of conditions.

Brown-Rot. There is a rarer rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.) Schrt.) than that of black-rot, which also attacks the apple in some parts of the United States. For our region it is little known on the apple and probably less important than either of the preceding.

Brown Spot or Dry-Rot of Baldwin. Very frequent complaint is made of small sunken spots in fine specimens of Baldwin and some other varieties. Internally these sunken spots are dry and somewhat bitter, leading to general breakdown of the apple. These spots have been referred to a particular fungus, (*Phyllachora pomigena* (Schw.) Sacc.,) but the case is not proved. This internal brown spotting also occurs in Northern Spy and in Fameuse, and we hear complaint of losses from it. The causes of the internal spotting are probably the same in all cases and must in part be regarded as physiological breakdown. New Hampshire Experiment Station (Bulletin 45) succeeded in controlling the form of this dry-rot on Baldwin by the use of Bordeaux mixture. Some irregularity in results from spraying for it have been recorded elsewhere.

Canker. These diseased conditions upon branches may occur in the propagation of bitter-rot, but are more commonly referable to the black-rot fungus, (*Sphaeropsis malorum* Pk.,) or to the blight bacterium (*Bacillus amylovorus* (Burr.) De Toni (See Bul. 163, N. Y. Experiment Station and Bulletin 235, Cornell Experiment Station) although other fungi are common in Europe as the cause of canker. Among these are species of nectria. Probably the canker due to the black-rot fungus must contest with that due to the blight bacterium for first place in Ohio, and its control is interwoven with the control of the black-rot on fruit. Canker-like dying of the external bark may, and sometimes does, occur without immediate penetration to the inner bark layer or injury to the branch. All these cankerous developments are, however, a source of danger and call for continuous watchfulness. The conditions of the fungus attacks are those of possible rifts in the outer bark followed by the localizing of the fungus development. Those for the blight canker are more extended and include blossom spurs. (See twig blight and pear blight). It seems probable also that the power of resisting attack varies with the vigor of the branches. Up to this time our remedies have been largely

Fig. 29. Apple branches attacked by canker.

the general ones of germicide sprays with addition of scraping off loosened bark where possible; for this purpose a dull tool is preferable. Some forms which might be called canker on young trunks and on older branches are in fact forms of winter injury from freezing. Types of branch cankers are somewhat variable, but they are all matters calling for close attention.

Collar-Rot. (See Sun-Scald).

Coryneum or Orange Leaf-spot. During 1908 and 1909 specimens of an orange leaf-spot have been received, and a severe case of defoliation of apple trees in town was reported from Stark county. This leaf-spot is a central, erumpent pustule with an immediate border of orange yellow: this yellow area shades off into dark color toward the green tissue. Hartley has reported, upon investigations of the fungus in this case, *Coryneum follicolum*, that it is not actively parasitic. Possibly we have this fungus following something else, after the manner that another fungus follows the black-rot leaf-spot described below. (See also rust of apple).

Crown Gall. This disease is especially a nursery trouble of apple and shows its effects by enlargements near the crown or upon other portions of the stem or root. It is quite probably due to the same organism (*Bacterium tumefaciens* Erw Sm & Towns) as the olive knot or some other crown gall troubles. This is decidedly an infectious disease which probably calls for inspection of nursery stock, and for great care to provide against diseased trees. Cure of infected plants has not been secured. There is great danger in endeavoring to grow nursery stock upon land which was once infected with the organism.

Edema. An Edema or swelling of apple twigs has been described by Atkinson from New York (Cornell Station, Bulletin 61). This on closely trimmed trees on over fertile soil.

Fly-speck Fungus (*Leptothyrium pomi* (Mont. & Fr.) Sacc.) This obvious fungus disease in ordinary seasons appears chiefly upon apples grown in low, moist situations. Peck's Pleasant, Rhode Island Greening, Rome Beauty and several other varieties have been noted as affected by the Sooty Fly-speck troubles which may be identical as to cause. During wet seasons, like that of 1896 and 1909, a few susceptible varieties are liable to be spotted by this parasite whatever be the location of the trees. Aside from selecting high, sunny situations for the apple orchard, spraying with Bordeax mixture will prevent this spot. (See Sooty Fungus)

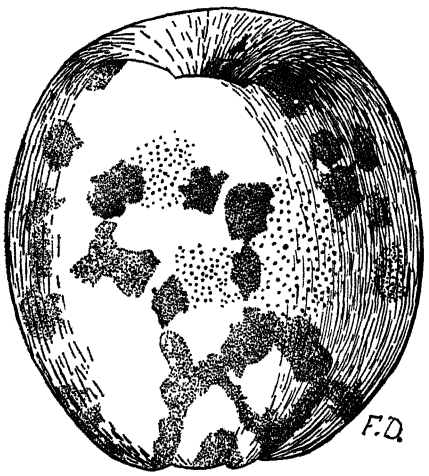


Fig. 30. An apple attacked by the Fly-speck fungus. The sooty fungus is also abundant on specimen as is usually the case.

Fruit Blotch. Fruit blotch is a recently described fungus (*Phyllosticta solitaria*, E.&E.) which causes a serious spotting of fruit in a number of ways as described in bulletins of the Illinois and West Virginia Experiment Stations, so that we may expect it to give trouble in Ohio. As indicated the fruit is attacked by this spotting and in addition the fungus produces small cankers on twigs. Scott has recently shown that it will be fully controlled by three or four sprayings with Standard Bordeaux mixture. (See Bulletin Bureau of Plant Industry).

Leaf-spot or Frog-eye. There is a common leaf-spot disease of apple trees in which the dead spots show the presence of pycnidia. This trouble is really due to the black-rot fungus (*Sphaeropsis malorum* Pk) but at times another fungus, (*Coniothyrium pirini* Sacc.), comes in afterwards. In the later season the second type develops in concentric areas to which the common name of "Frog Eye" has been given. Yet other forms of leaf-spot due to spray injuries also occur, but are easily distinguishable from the two first named. It has been shown that control of the black-rot fungus keeps the leaf-spot in hand, but early treatments should be made.

Mold. A blue mold is very commonly associated with soft rot of apples in storage. The fungus (*Penicillium glaucum* Lk.) is a very common one and may be regarded as associated with the presence of decay or bruising, not as a first cause of rot.

Mildew. The powdery mildew (*Sphaerotheca mali* (Duby) Burr.) often occurs upon nursery growths of the apple and occaionally upon rather thrifty growing young trees. The dense felt-like covering of the fungus is usually very apparent and the spreading of the fungus upon the foliage is sometimes noticeable. Spraying with fungicides usually keeps the trouble in check.

Rust. The bright orange growths of this rust fungus (*Gymnosporangium macropus* Lk., etc., I) are occasionally found on cultivated apple leaves as well as on leaves of wild thorn apples, especially where these are within reach of the cedar trees which bear the cedar apples. In 1909 the rust attacked apple fruits in Ohio and Nebraska. These so-called cedar apples are no more than the development of the rust fungus from which the spores are spread to the apple, Crataegus, etc. A remedy in indicated by this statement, viz., get rid of cedar trees.

Root-Rot. Serious root-rot troubles have been reported to us from Missouri, Arkansas and Oklahoma where orchard plantings have been made quite soon following the clearing of scrub oak, etc. Similar cases have been studied in Ohio where plantings were made soon after the removal of the timber, especially of oaks. One is usually able to identfy the rhizomorphs of the root-rot fungus, (*Agaricus melleus* L. (*Armillaria mellia*) and the characters by the occurrence upon orchard trees and also the original growth is usually quite clear. Any inadequacy of drainage is very serious in connection with root-rot. (See root-rot of peach, etc). More recently Von Schrenck has identified another fungus (*Thelephora galactinia* Fr.) with a form of root-rot which shows no superficial symptoms until after the tree is dead; it then shows the orange, leathery sheets.

Scab. Apple scab fungus (*Venturia inequalis* Aderh, *Fusicladium dendriticum* (Wallr.) Fuckl.) is a common source of large losses in Ohio apple orchards. It attacks first the leaves and afterwards the young fruit, causing it to drop. Aside from injuring the salability of the crop obtained and reducing the vigor of the tree by reason of its attacks on the foliage, *scab may prevent a crop altogether because of this dropping of the young apples.* The Ohio Station was in the van of progress in studying this disease, and the work has been steadily followed (Bulletin Vol. IV, No. 9, (1891) B. 79, (1897) B. 111, (1899). Full details may be found in the various bulletins given. Apple scab develops when moisture is abundant during the early months of she season, and low temperatures are usually prevalent at such times. The dropping of apples often attributed to lack of pollination seems more often to be ascribed to the work of scab. All varieties are attacked by scab but some suffer more than others.

The profit from spraying for scab on the apple (including apple worms) has generally been large, because of saving the amount of crop and enhancing its market value at the same time, as well as increasing the number of crops. In this way the crops of a single orchard have been sold for a gain of about $1000 on an expenditure of $125 to $150. At the Station this gain has amounted to $5.00 per tree (B. 111). The best fungicide for this purpose is dilute Bordeaux mixture, or Bordeaux I of the spray calendar, containing 4 pounds of sulfate of copper and 4 pounds of quicklime to 50 gallons of mixture with water, or Bordeaux mixture and Iron Sticker consisting of 2 pounds of copper sulfate, and 2 or 3 pounds of iron sulfate in 50 gallons of water. The Bordeaux mixture and Iron Sticker has given better results in a rainy season like 1909. The first spraying should be made just before the blossoms open, and upon the young leaves, and the second after the blossoms drop, with additions of arsenites in the second and in a possible fourth spraying as stated in the spray calendar.

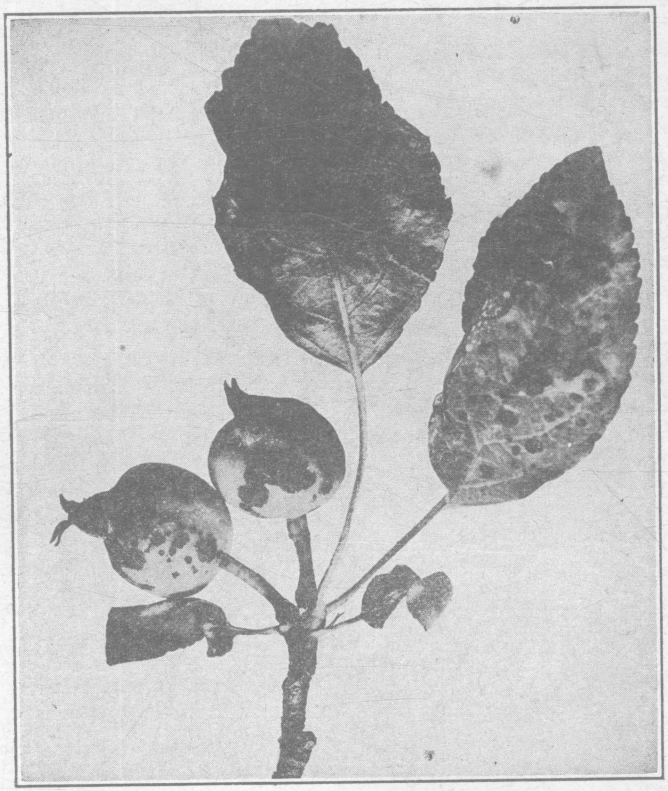


Fig. 31. Young apples attacked by the scab fungus (*Venturia inequalis* Aderh).

Scurf. The branch scurf fungus (*Phyllosticta prunicola* Sacc.) is believed to occur in Ohio. This causes roughening of the bark, but no statements can now be made as to its possible seriousness.

Sooty Fungus. The sooty fungus (*Phyllachora pomigena* Schw.) is often associated with the fly-speck fungus, previously described, and is the more unsightly trouble of the two. In most seasons the fruit in low situations is

liable to be rendered unsightly and unsalable by the spots which are illustrated in Fig. 32. In seasons like that of 1909 the disease may appear on unsprayed trees in practically all situations. It was found in comparative tests of Bordeaux mixtures and self-boiled lime-sulfur for apple scab and other fungi, at the Carpenter test farm, that the sooty fungus appeared on the fruit on the lime-sulfur trees. It is thought by several that this fungus spreads upon the fruit after it is stored and at whatever time it appears it renders apples dull, unsightly and unsalable. Bordeaux mixture or its modifications may be relied upon to hold the fungus in check. One spraying at the time the apples are the size of hickory nuts may prevent nearly all of the injury. Upon varieties like Maiden's Blush, Grimes and Belmont the spraying should be done a little earlier than just stated. The demonstrations by the Station all over the state, show clearly what improvement the spraying makes in the apples where this trouble prevails.

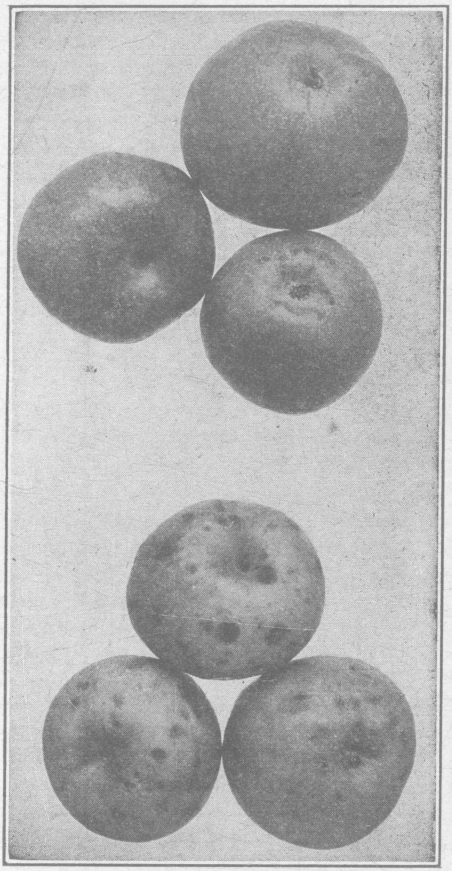


Fig. 32. Apples spotted by sooty fungus. The apples shown above were sprayed with Bordeaux mixture followed by two sprays of Bordeaux and Iron Sticker. The apples shown below were sprayed first with Bordeaux mixture and this was followed by two sprays of self-boiled lime-sulfur. In neither case was the scab entirely prevented. The lime-sulfur spray was not strong enough to keep off late attacks of sooty fungus. From a photograph by T. F. Manns.

Sun-Scald, Collar-Rot. There is frequent complaint of the dying of the trunk of both younger and older apple trees wherein there appears to be associated the exposure to sun and the death of the bark of the trunk upon younger orchard trees. The freezing injury has been carefully worked out in recent years and is discussed under winter injuries, with several varieties of apples, notably the Grimes and King this trouble is so serious over much of Ohio as to reduce the growth of these sorts; while Murrill has suggested a connection between a fleshy fungus and this dying of the trunks of the King the connection has not been proved. The injuries which occur on the south and southwest exposures of the trunk have probably a direct connection with the danger from freezing injuries. Some apparent sun-scald is more probably due to the bacterium of pear blight as has been recently proved by cultures from young trees by Waite. With Grimes and other varieties susceptible to collar-rot caused by the bacterium of pear blight the only true relief is found by top working on some vigorous sort such as Baldwin, Gano, and like varieties. In the case of true

sun-scald the effect of freezing is to form an ice layer and thus separate the bark or in the case of many water gorged cells to kill the sap layer. For further discussion in this line see winter injury.

Storage Rots. These rots of the apple are extremely various since apples infected before storage are liable to develop during storage the forms of rot due to that infection. Even bitter-rot may not be overlooked in this way and much more commonly still, black-rot and the rots which develop from the gradual invasion of molds. It is found, futhermore, that bruises upon the apple or any tendency to sun scald phenomona give dead tissues in which various saprophytic organisms that normally hasten decay will do their work with rapidity. It is understood, of course, that the temperatures of storage will regulate or control more or less perfectly the rate of this development. Storage scalding of apples is much worse in some varieties, notably in York Imperial than in the normal toughened skin types. At present one can only suggest the rejection of those sorts susceptible to scald for cold storage keeping.

Twig-Blight. This disease of the apple, caused by the bacterium of pear blight (*Bacillus amylovorus* Burr.), is often very prevalent. The microbe enters through the blossoms, being propagated in the nectar after infection by insect visitation. It destroys the blossoms as well as small twigs of the tree. Beyond the injuries just noted this microbe may gain entrance through the bark. (See sun-scald). The twig injury is not very great from this cause on the apple, though the small dead twigs are unsightly. The prevention will lie in the destruction of all the blighted parts on apple, crabapple, pear and quince trees in the vicinity. For fuller discussion see pear blight. In substance, this treatment consists in cutting out all blighted portions in fall and early winter and burning them to kill the resting forms of the microbe. It seems further that well timed, early spring spray treatments on pear, etc., will cover up or destroy spores of the blight. (See Circular 87).

Water Core. With the so-called Russian apples and occasionally with other varieties as Yellow Transparent and Early Harvest, there are water core conditions, at times, which may result in subsequent rotting. No explanation is here offered as to cause for the condition.

Winter Injury (also called Sun-Scald). As previously mentioned there are a number of evidences of injury which involve the trunks of apple trees of all sizes; they are many times due to freezing injury; while this name winter injury appears at the beginning of the paragraph and while the name sun-scald has been applied for a long time to similar conditions, the injuries are directly due to freezing, sometimes occuring in winter and sometimes, as in October 1906, due to premature low temperatures. A conspicuous case occurred in the fall and winter of 1906-7, more fully described in the bulletin devoted to these injuries (Bulletin 192). At that time as in other cases of injury from freezing, the low temperatures accurred when the trees were gorged with water (sap). In the fall of 1906 we had very heavy rainfall with low temperatures so that there was stimulus to excessive water absorption and no tendency to hasten ripening of tissues through water loss and reduced water content such as occur in dry autumn periods. The losses of young trees set one to three years, were very large in the winter of 1906; indeed, in some cases there was practically a total loss as on slow growing varieties, notably the Rome Beauty in the Station plantation at Carpenter. In general at that time the typical late variety of the northern part of the state, Baldwin, and of the southern portion, Rome Beauty and the Hubbardson were most seriously injured. It is evident that where we have such excessive water supply in the inner bark and in the process of freezing, a layer of ice crystals

is formed. There is great danger of separation of the bark layer from the wood at that time as at others. The sun exposed side seemed to have suffered worse by reason of the more extreme temperature changes which were incited on these exposures. It is evident that warm periods in winter are a source of danger when followed by low temperatures.

Upon very large trunks near the base, as on Grimes and some others, this may be the real explanation of frequent sunscald or basal injuries. Wherever such an injury begins there is risk of the intrusion of wound fungi with all the consequences which follow their entrance. The handling of winter injuries must so far as prevention goes precede the conditions which cause it. Where possible the prevention of excessive late growth is desirable. In cases of orchard trees it may be that mulches of coarse litter, especially, will prove serviceable. It may be added that this injury to woody growths is a less developed phase of the killing back of herbaceous plants by the premature frosts.

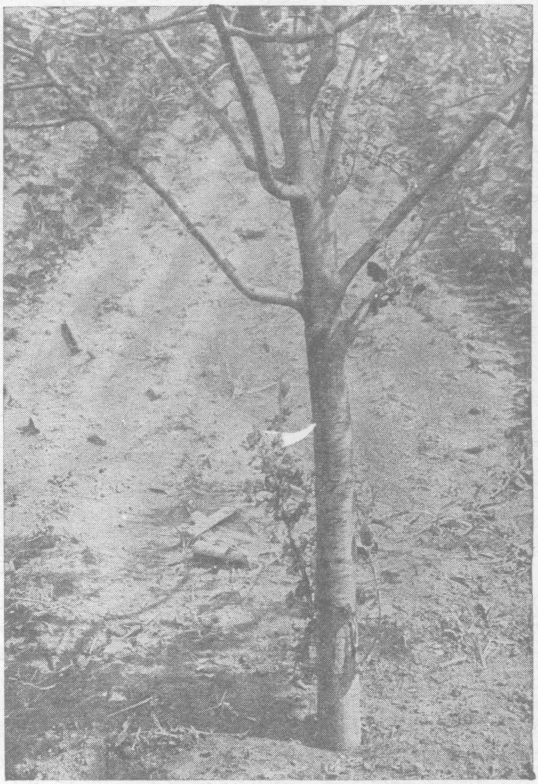


Fig. 33. Jonathan tree, 4 years old, Southeastern test farm, Carpenter, in cultivated portion. Tree of vigorous previous growth with small lesion near base of trunk caused by freezing and sprouts from below. Photographed July 20, 1908. From Bulletin 192.

Another phase still is the killing back of branches at the tips of woody growth which are not strictly hardy in our climate. In the case of our Japanese plum and of some ornamental shrubs, this is a frequent phenomenon and its cause is to be sought in the same factors above described. Growth being protracted late in the season, these water gorged terminal twigs are killed by the subsequent winter freezing whenever this is severe.

APRICOT

The apricot is rarely planted though occasionally is set in our Lake Districts. The chief difficulties there have been the tendency to kill back in winter. Apricot foliage in addition is liable to be attacked by the similar leaf parasites of peach and plum.

ASH

Trunk Rots. The ash as a forest and shade tree is a vigorous grower, but it is often marked by the attacks of timber decays where these enter through wcunds or by means of the bases of dead branches. We have urgent need for more knowledge of these wound parasites.

Leaf-Spots and Rust. I may also state that the foliage of the ash is attacked by rust (*Puccinia fraxinata* (Lk.) Arth.) but in the present state of our knowledge we are unable to apply effective remedies. This rust, as in the case of other rusts, shows by the presence of its reddish or brown colored spore masses. Of leaf-spot fungi there are a number which call for careful study.

ASPARAGUS

Anthracnose. An anthracnose fungus of asparagus (*Colletotrichum* sp.) is known in New Jersey but has not been frequent, if present, in Ohio.

Rust. In the east and in Europe the rust of asparagus (*Puccinia Asparagi* DC.) proves to be destructive, and it has finally spread over Ohio.

Fig. 34. Asparagus attacked by rust. The rust causes elongated development of the fungus, both upon the stems and leaves of the plant.

The rust causes appearance of unusually early maturing of the plants. Closely examined the rusted plants show blister-like spots on skin of the stem, and underneath these ruptures there is brown color due to the spores. The rust also assumes another form, the cluster-cup stage, which may be found in early spring with different color on volunteer plants; indeed the aecidial, or cluster-cup, uredo and teleutospore stages succeed each other on the stem. The usual recommendations are to burn the rusted bushes in autumn and to spray with Bordeaux mixture; this latter "reduces the amount of rust about one quarter." (N. J., B. 129). The Leopard spot of asparagus stems is apparently not infrequent, and the anthracnose of asparagus, which produces very small specks upon the stem, may also be expected, yet neither of these compares with the rust in destructiveness, nor does the rust of any other plant appear to surpass this in its ravages. The Palmetto variety is reported less susceptible to rust than any other sort.

AZALEA

Leaf-Spots. This plant is grown as an ornamental plant and whether in hothouses or in protected planting out doors, is liable to injuries from leaf diseases. One of these is a leaf-spot fungus (*Septoria azaleae*). It is also liable to attack by a "bladders" fungus upon the young parts.

BARBERRY

Rust. The rust upon the barberry bush (*Aecidium Berberidis* Gmel.) is but a form or stage, the aecidial or cluster cups, of the wheat rust (*Puccinia graminis P. rubigo-vera* etc.). The increase of virulence in the rust of wheat and rye, when grown near barberry bushes, was long noted before the demonstrated

alternation of the fungus from the barberry to the wheat was proved in our century by DeBary. The barberry hedge is objected to, at times, by adjacent wheat growers, although we continue to suffer from the ravages of wheat rust many miles from any barberry bushes. In the absence of barberry the rust survives without it.

BARLEY

Rust. In the west and northwest there are two forms of rust; leaf rust (*Puccinia simplex* (Koern.) Erikss. and Henn.) and stem rust (*Puccinia graminis* Pers.). These rusts, like those of the other cereals, have not yet been mastered or controlled.

Scab. Barley is attacked by scab (*Fusarium roseum* Lk.) in a manner similar to that which occurs on wheat and rye. That the scab fungus is the same for all grains has been shown by recent work of this department. (See Bulletin 203).

Seed treatment for the loose spores and seed recleaning to get out the shrunken and scab infested kernels ought to give favorable results. (See wheat scab).

Smuts. The covered barley smut (*Ustilago hordei* (Pers) Kell. & Sw.) as well as the naked barley smut (*Ustilago nuda* (Jens.) Kell. & Sw.) both occur in Ohio, although barley is grown less extensively with us than in the west and northwest. In the covered barley smut, the smutted heads more commonly remain enclosed by the upper leaf sheath and a membrane holds the smut masses, while the spores are exposed and freely scattered in the naked barley smut.

The modified hot water treatment for loose smut of wheat has been found effective upon the barley smuts. See Farmers' Bulletin No. 75, Yearbook U. S. D. A., 1894. Spray Calendar, Bulletin 199.

BEAN

Anthracnose. The anthracnose of the bean causes unsightly spotting of both pods and growing organs and is referred to the anthracnose fungus (*Colletotrichum Lagenarium* (Pass.) Hals.). This species is also regarded as the same one that attacks curcurbits, including cucumbers, watermelons, muskmelons and gourds. The spotting of the bean pods is looked upon, too commonly, as a natural phenomenon. Measures looking to its prevention have not found ready application by growers. That fungicides are effective in reducing it we have reliable testimony (N. J. Exp. Sta. B. 108). The recommended treatment begins by soaking the seed 1 to 2 hours in ammoniacal copper carbonate, 1 ounce of copper carbonate to 1½ gallons of water. Bordeaux mixture is to be sprayed upon 2 and 3 inch plants, followed by the same 10 days later, and again repeated after blossoming of plant. The great thing to remember is that this is a seed infecting disease. We must grow disease-free seed. (See Pea).

Bacterial Spot. A bacterial blight has been reported from New York (N. Y. Exp. Sta. B. 181) and New Jersey (Exp. Sta. Rept. 1892) which promises more or less injury. In this malady the diseased parts, leaves, pods, etc., show characteristic, often watery spots. It is less prevalent on fresh land. The organism (*Bacterium phaseoli* Erw. Sw.) is widespread.

Downy Mildew. This fungus (*Phytophthora Phaseoli* Thaxter), so far as known at present, has not been found in Ohio, though occurring to a destructive extent in the east, and liable to occur in our vegetable gardens. Experiments have shown that it is controlled by spraying with Bordeaux mixture.

(Conn. Exp. Sta. R. 1897, Pt. III). In this instance, as with the downy mildew of cucumber, it is probable that August 1 is sufficiently early to begin the application of the fungicides.

Powdery Mildew. Powdery mildew of the bean is due to the same fungus as the powdery mildew of pea, for which see pea.

Rust. This fungus (*Uromyces appendiculatus* (P.) Lev.) is often observed to produce reddish brown spore masses upon both surfaces of the leaves of beans. It is perhaps rather more variable in occurrence, and certainly less injurious in the past than bean anthracnose. It has been quite common in Ohio. Beyond burning diseased refuse we are not prepared to suggest remedial or preventive measures.

Stem-Rot. The root-rot fungus (*Rhizoctonia*) attacks the bean root and stem and at times spots the pods in the south.

BEECH

Anthracnose. The anthracnose fungus (*Gloesporium Fagi* (Rob.) of beech attacks the leaves, but is not so serious as many of the other anthracnoses.

Leaf Diseases. While the beech is not largely planted, it is nevertheless a useful shade tree. The leaves are often attacked by two or three mildews (*Microsphaera erineophila* Pk. & M. *penicillata* (Wallr.), also *Phyllactinia suffulta*), which, however, rarely gives serious injury to foliage. In Europe the beech is attacked by a rust fungus (*Melampsora Fagi*); the leaves are also attacked by a leaf-spot species of Phyllosticta.

BIRCH

Anthracnose. The anthracnose fungus of birch (*Gloeosporium Betularum*, E&M) attacks the leaves of our American birches while other anthracnoses are known on the European species. Our knowledge of the injury is very limited.

Mildews. The downy mildews of beech and alder in part occur upon the birches.

Wound Fungi. Characteristic fleshy fungi invade pruning or other wounds in the birch and are to be guarded against as with other woody growths.

BEET

Leaf-Spot. The garden beet is quite liable to the attacks of the leaf-spot fungus (*Cercospora beticola* Sacc.) which causes serious impairment of leaf action and premature dropping of the foliage. Other changes are likely to follow those stated. This trouble may be controlled by the use of Bordeaux mixture at fortnightly intervals. (B. 199). The leaves of beets are also attacked by a white mold (*Cystopus Bliti* (Biv.) Lev.) although this latter fungus is less frequent and less ruinous than leaf-spot. The same fungicide may be used if required. See "sugar beet" for other diseases.

Scab. The scab troubles on the beet are similar to those on the potato and are referred to the same fungus. This trouble is likely to follow where beets follow in soil that has been diseased with either beets or potatoes.

Root-Rot. (See sugar beet).

BEGONIA. (See Pelargonium).

Nematodes. These minute worm parasites attack the roots and also the leaves of cultivated begonias (Ohio Exp. Sta. B. 73; N. J. Exp. Sta. Rept. 1894). For the commoner root injury avoidance is to be sought in the preparation of the earth.

Root-Rot. The root-rot fungus of violets and tobacco *Thielavia basicola* Zopf.) was found attacking the roots of begonia which suffered from nematodes. Its general occurrence since the discovery upon tobacco and catalpa show that it is capable of serious injury to the roots of these cultivated plants.

BLACKBERRY

Anthracnose. The anthracnoses of blackberry and raspberry (*Colletotrichum venetum* Speg.) are identical and are described under the raspberry.

Leaf-Spot. This disease is also common to the blackberry and the raspberry, although the latter is less commonly attacked. This fungus (*Septoria Rubi* West) is conspicuous upon the wild growth and upon the trailing dewberries; it produces, usually, small, light-gray spots in the leaves and yields to treatment with the standard fungicides. (See Ohio Exp. Sta. B. IV, 6, and B. 79).

Crown Gall. Is apparently of a similar contagious nature to that of the raspberry. It is of like appearance, though the galls at the crown of the plant are often larger. A plant once attacked is incurable, and offshoots from it appear to be generally affected, thus calling for immediate digging and burning of all the diseased canes and the abandonment of propagation from such plantations. (See raspberry crown gall).

Red Rust or Bramble Rust (*Caeoma nitens* Schw.) is a well known disease of the wild and cultivated blackberries, which also attack raspberries. It causes the affected leaves to turn first yellowish in color, remain erect in position, and finally to become bright red with an abundant coating of the spores of the rust fungus. These spores are readily scattered and may thus affect previously healthy plants. The threads of the rust fungus (mycelium) live year after year in the affected plants. For this reason the only remedy is to dig and burn all members of the rusted stools. (See Bulletin 79).

Root Diseases. Recent examinations of blackberry plantations show root diseases of undetermined cause. The affected roots show brown spots as if parasitized and the growth is seriously curtailed. Recent conditions in blackberry plantations indicate root parasites since sections of the roots become discolored and the growth of the canes is checked. These have not been sufficiently investigated for exact determination at this time.

BLUE-GRASS

Anthracnose. In the summer of 1908 the anthracnose fungus of wheat, rye, oats and other grasses (*Colletotrichum cereale* Manns) was discovered on blue-grass in Ohio. This shows as black spots on the stems and basal sheaths, and will evidently survive on this pasture grass. The injury is greater upon wheat, rye, oats and clover, under which illustrations are given, than upon blue-grass.

Bacterial Blight of Head. In a recent bulletin from this department (No. 210), Manns has described the organisms of blade blight in oats and has reported a head blight in blue-grass and timothy caused by them. In this case the bacteria appears to enter the upper sheath and cause a lesion above the upper joint. This ends in the death and the drying up of the heads.

Powdery Mildew. The foliage of the blue-grass is attacked by the conidial stage of the wheat mildew (*Erysiphe graminis* DC). This fungus gives little evidence of injury, though its presence is certainly *not* beneficial and the perithecia of the parasite are not common on this host.

Rust. Blue-grass is likewise attacked by a rust (*Puccinia graminis*) which is general on grasses.

Smuts. A smut fungus (*Ustilago striaeformis* West.) attacks the blades of blue-grass though it is possibly not often very injurious.

BROOM-CORN

Smuts. Of these there are two, head smut (*Ustilago Reiliana* Kuhn.) and grain smut (*Cintractia Sorghi-vulgaris* (Tul.) Clinton), the latter of which is prevented by treating seed for 15 minutes in hot water at 135 degrees F. and drying

for planting as for oats. The same smuts attack sorghum and are very likely to occur in foreign seed. (See Kansas Experiment Station Bulletin 23; Ills., Bulletin 47).

BUCKWHEAT

Leaf-Blight. This well known plant is frequently attacked by a leaf-blight fungus (*Ramularia rufo-maculans* Pk.) which produces whitened areas on the under leaf surfaces and causes dying of these leaves. It is not known to be sufficiently destructive to warrant treatment for prevention.

Another leaf trouble referred to a fungus (*Fusicladium fagopyri*) is reported from Europe, but is not known in our climate.

CABBAGE-CAULIFLOWER

Brown- or Black-Rot is a serious disease of these two crucifers, and attacks others of the family, including turnips. It is a veritable scourge to the cabbage growers of Ohio and other states. Smith (Farmers' Bul. 68, U. S. D. A.) has published concerning it and has attributed the disease to a specific germ (*Bacterium campestre* (Pam.) Erw. Sm.). The diseased heads may be dwarfed, in portions rotted, and brown colors will appear in the woody layers of the plant, including the stem. Badly diseased heads emit a penetrating and offensive odor.

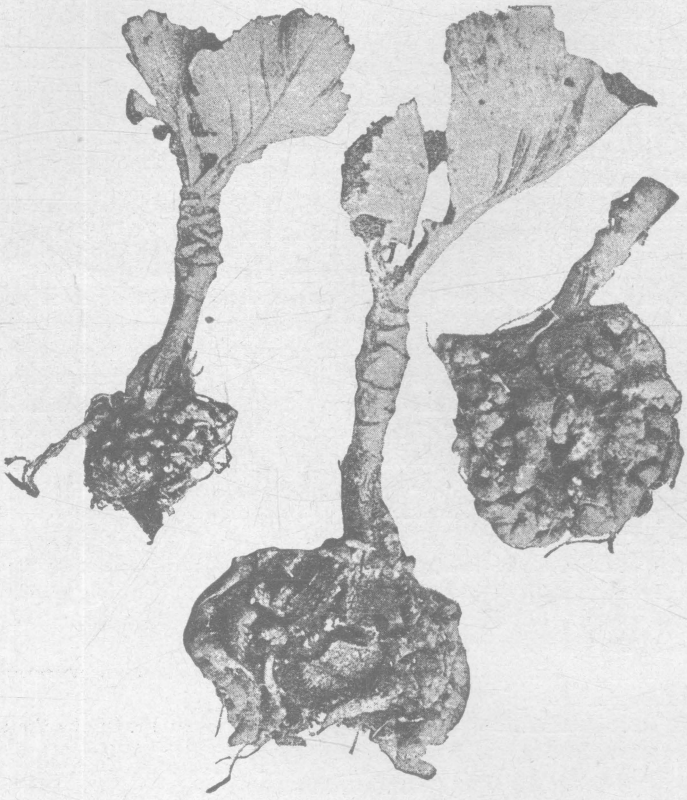


Fig. 35. Young cabbages partially affected with club-root The club-root survives in the soil and causes swellings and abnormal forms of the roots. After Halsted, Bul. 98, N. J. Exp. Sta.

The losses from the brown-rot have been very large and specific remedies cannot be stated. The author quoted sums up the subject of treatment in one word—prevention. The measures recommended are—plant on new land and only from healthy seed beds; avoid succession of the same crops; avoid stable manure and give preference to artifical fertilizers to escape possible infection through the manure. Prevent animals from cropping in diseased fields. Clean tools by scouring bright after use in infected soil. Fight the cabbage insects, since these inoculate healthy plants with the disease. Removal of badly affected plants, or newly infected leaves, at intervals, and subsequent burning or deep pitting of this refuse may aid in checking brown-rot. Destroy all mustard weeds. See page 318 for part played by water pores in the infection.

Club-Root. Club-root fungus (*Plasmodiophora Brassicae* Wor.) attacks these plants as well as the turnip, rutabaga, wild shepherd's purse, hedge-mustard and certain other plants of the mustard family. It is called finger and toe disease in England. It causes enlargement of the roots and prevents growth of normal head or root. (See figure, p. 380).

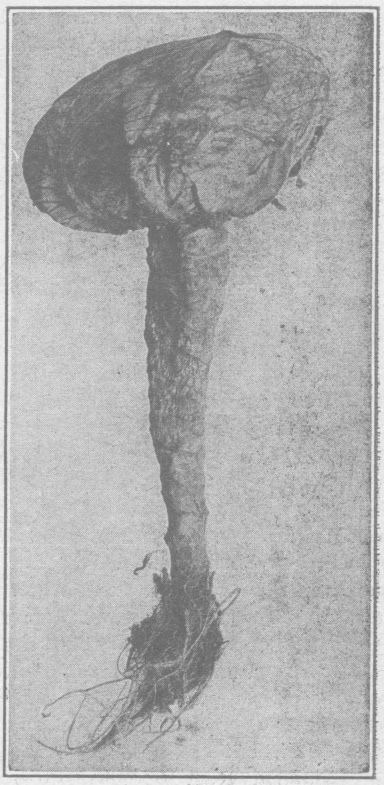


Fig. 36. Cabbage plant attacked by Fusarium wilt. This has caused the leaves to yellow and drop and the plant has produced no marketable heads. The lesion caused by wilt fungus may be observed upon the left-hand side, upper half of stem. From a photograph by T. F. Manns.

This fungus is harbored in the soil, so that if the land is once infected the disease may prove lasting. It has not yet been learned how long the trouble will survive if the soil is planted in other crops. Lands newly brought under cultivation may be infected with club-root through the wild mustard plants upon them. It would appear possible by watchfulness to avoid getting the club-root fungus into cabbage lands; the seed bed should be most carefully guarded from this trouble as from rot. It will be much cheaper to abandon the crop for some other, when the plant bed has become affected with club-root and the seedlings have enlarged or whitened roots from this disease.

In New Jersey, Halsted has investigated this trouble and has found (N. J. Exp. Sta. B. 98 and 108) that fresh stone lime, if applied at the rate of 75 to 80 bushels per acre upon freshly plowed land in spring, and worked into soil, will very greatly reduce the amount of club-root on turnips and cabbage; there is no reason to doubt that this treatment is applicable to all plants of the order attacked by club-root.

Downy Mildew (*Peronospora parasitica* DeBy.), Leaf-Blight (*Macrosporium Brassicae* Berk.) and White Rust (*Cystopus candidus* (P.) Lev.), occur upon the mustard plants, including, perhaps, all named above and some others. As yet their presence has not proved a serious drawback. If to be treated, Bordeaux mixture should be applied.

Wilt. The fusarium wilt disease earlier reported from the eastern truck districts, is now very destructive in Ohio. In 1909 it locally destroyed nearly all the crop where either infected plants were set upon fresh soil or plants were set on infected soil. It causes a yellowing and wilting of the plants sometimes with apparent stem injury. In our cabbage districts it may be this wilt is to contest with black-rot for first place in rank of injury done. The remedy lies in breeding wilt resistant strains of cabbage.

CALLA

A Root-Rot of callas has been studied by Halsted and Townsend. The disease appears to be due to bacteria (N. J. Rept. 1893). Reject rotted roots.

CARNATION

Bacteriosis of carnations has been reported upon by Arthur and Bolley (Ind. Exp. Sta. B. 59). This causes many small, brownish spots with yellowing of the leaves of the affected plants. Such are feeble in growth and deficient in return. The maintenance of best and most favorable growth conditions may often be effective in preventing this trouble; particularly sub-irrigation and war on aphides are to be recommended.

Bud-Rot. A serious rot of carnation (*Sporotrichum antrophilum* Pk.) is reported from several states and is doubtless present in Ohio.

Leaf and Calyx Mold (*Heterosporium echinulatum* (B.) Cke.) (Fairy Ring) of carnations is often very unsightly upon the calyces and pedicels of these flowers; it also attacks the leaves. All sorts appear to be more or less parasitized with the fungus in the houses where it prevails. Yet another spotting is produced by the carnation leaf-spot fungus (*Septori Dianthi* Desm.), which has appeared at this Station more frequently upon the Daybreak variety. It is believed that both these fungi will yield to treatment with Bordeaux mixture as per calendar. (See Bulletin 73).

Carnation Rust (*Uromyces caryophyllinus* (Schrk.) Schroet.). This rust fungus is one of the serious diseases of the carnation. There is some differerence in the liabitity of varieties to the disease, and perhaps a much larger difference in the condition of the stock plants from which cuttings are made. Assuredly this matter of "cutting stock" is of very great im portance and one admitting of selection of the very best plants. Experiments conducted at this Station in 1896 by the writer and the Station Florist (See B. 73) yielded no gain from spraying with Fowler's solution, which has been sometimes recommended. Watchfulness in the destruction of rusted parts, and in the stock for propagation, are suggested for the control of rust.

A Root- or Stem-Rot (*Rhizoctonia* and *Fusarium*) of carnations has been noted by Stewart (Bot. Gaz. XXVII, 129, 130) and occasional rotting of the flowers through the presence of a Botrytis. For the former no thoroughly effective remedy is now at hand, while general cleanliness of the house is necessary to avoid the rot fungus Botrytis. (See Lettuce Rot).

CANNA

Rust. Foliage of canna is sometimes attacked by a rust which may be identified by the characters of its fungus (*Uredo cannae*).

CANTALOUPE

See Muskmelon.

CARROT

Leaf-Spot. This spotting of carrot leaves is usually caused by the same fungus (*Cercospora Apii* Fres.) as the celery leaf-spot. Upon the carrot the trouble is not usually serious.

CEDAR

Cedar Apples or Cedar Rust. During the showers of April, May or Juue, large or small, jelly-like masses, often one inch or more across, with firmer wood-like centers, are frequent upon red cedar trees and upon similar related plants. Microscopic examinations of these jelly masses show that they contain the spores of a rust fungus (*Gymnosporangium macropus* Lk. and other species of Gymnosporangium). This fact need not startle us but for another, namely, that this is the completed or teleutospore stage of a rust which may seriously injure the leaves of the apple. The apple grower will run some risk then, in having about him diseased cedar trees. The remedy lies in the destruction of the cedar trees.

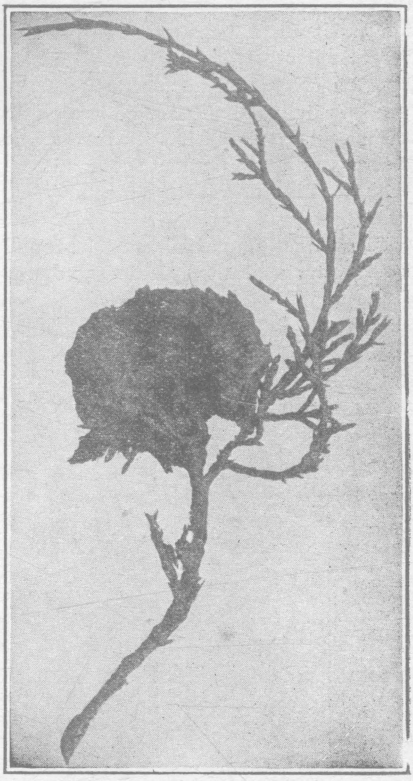


Fig. 37. Cedar apples caused by rust fungus. In May these dry looking apples send out jelly-like branches filled with spores of the rust fungus. These spores may attack leaves and fruit of apple, as well as crataegus and juneberry. (From a photograph by W. P. Beeching).

CATALPA

Leaf Blight. Leaf blight of catalpa has recently been troublesome to growers and puzzling to the Pathologist at times. The sudden blackening and dying of the leaves in early summer has been traced to frost, but other times in later summer to root-rot, which see. Frequently we have found a leaf blight fungus (*Alternaria* sp.) which developed freely upon the spotting leaves and appeared to be responsible in conjuction with some other rather unfavorable conditions for the young trees. This will probably give more trouble in the culture of the catalpa than the leaf-spot or mildew which have been known much longer and prove less serious. Early applications of Bordeaux mixture repeated at moderate intervals should check the disease.

Leaf-Spot. The leaf-spot (*Phyllosticta Catalpae* E. & M.) is quite frequent upon the leaves of catalpa. It rarely causes more than occasional spots in the leaves, the injury being in no way comparable to that caused by the catalpa midge. Fungicides should be effective against the true leaf-spot.

Mildew. The leaves of catalpa are often covered over by the powdery mildew fungi (*Microsphaera elevata* Burr., *Phyllactinia suffulta* Reb.). These mildews tend to become conspicuous by the white covering upon the leaves in later summer. While unsightly the injuries are rarely serious.

Root-Rot. Since the recent demand for seedling trees of Catalpa speciosa, some difficulties have been met with in diseased seedlings of catalpa. These seedlings are liable to be attacked in their early stages by the ordinary damping off fungi such as Rhizoctonia, Pythium and Botrytis. One interesting case of a true root-rot fungus was studied in 1908. The seedlings were being grown in land that has been used some years for truck gardening; the stand was cut down very much and in later summer some of the seedlings, then a foot or more in height, showed sudden dying and dropping of the leaves; this was found to be due to the root-rot fungus of the violet and tobacco (*Thielavia basicola* Zopf.). This must have been quite serious on the smaller seedlings. At the date of study, September, only the smaller root branches were destroyed by it and the larger ones seemed normal. The injury to these seedlings in dry weather was enough to bring about leaf collapse due to reduced water supply. If this fungus becomes very general it will involve soil treatment for such seed beds. It was too soon to determine how serious it may be upon trees of larger nursery size, although it is not greatly feared.

CELERY

Black-Root, so-called, may be found on celery plants from seed beds. In one instance such plants yielded growths which shortly run to seed and were valueless.

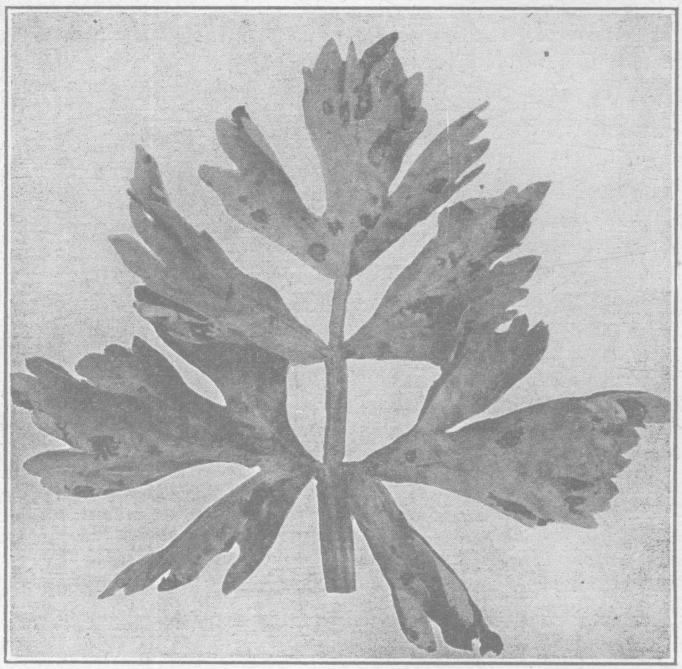


Fig. 38. Celery leaf attacked by leaf-spot. Various troubles produce similar spotting in celery leaves.

Leaf-Spot or Leaf Blight (*Cercospora Apii* Fres.) is a prevalent condition upon celery plants. This is at times attributed to the fungus above named, or others, and is also produced by other causes, as by excess of water during overflow and the like. During certain seasons the loss from the leaf-spot or leaf-blight troubles is very much greater than during others. This is clearly explained when the conditions giving rise to the leaf troubles are apparent.

But this is by no means a common fact, and in some years there is much blighting after the celery has been boarded up for blanching. Usually the fungus is discoverable in diseased areas of the leaves. The use of fungicides, such as Bordeaux mixture, is likely to prove beneficial, especially to protect the plants in the seed bed until transplanted. (See Spray Calendar). While beneficial for later applications in the field, so long as it is not clear that the fungus parasite is not the only cause of blighting or leaf spotting, all possible conditions should receive attention. Kinney (Rhode Island Exp. Sta. B. 44) has suggested that the breaking down of the celery leaves arises from the methods of culture practiced, particularly the level culture, in which the water relations of the plant are not in a natural state. He succeeded in preventing the blighting of celery by mulching with celery tops in which there was a large supply of the fungus. Mulching, especially during periods of prolonged drought, may thus prove profitable. The identification of the particular fungus occurring in the spots must, in each case, be made by the misroscope. Aside from the mulching suggested the remedies are stated in Bulletin 121.

The conditions of celery culture are yearly becoming more troublesome and are really serious.

Fig. 39. Younger celery plants attacked by root-rot. These plants are kept alive by new roots, though they increase but little in size. After VanHook, Cir. No. 72.

Heart-Rot is a very destructive decay of the inner, or heart, portions of the celery plant after blanching has begun. The inner parts rot very suddenly, emit a penetrating odor and the market value of the affected celery is destroyed.

The decayed parts are teeming with motile bacteria to which this form of decay has been attributed. The heart-rot prevails too in very hot, steamy weather, but preventive measures are about all that can be recommended. It is suggested that when the boards are first put up to the celery, under such conditions as accompany the heart-rot, they should be left apart at the top and only closed up to the usual point after an interval of several days. This secures better ventilation and often prevents the disease.

Root-Rot. During a succession of wet seasons much trouble developed in the Akron district from attacks of root-rot (*Rhizoctonia*). This gave trouble at times with the seedling plants, but more seriously with the shortened development of the crop. Often the roots were nearly all rotted off. The trouble seemed to decline rapidly with drier seasons. (See Circular No. 72, Ohio Exp. Sta.).

Rust, true and false. In Europe the celery plant is attacked by one or two rust fungi (*Puccinia bullata* (Pers.) and *P. Castagnei* Thum.) of the same class of parasitic fungi as those producing rust in wheat. These two rusts have not as yet been discovered in America, though they will doubtless in time become introduced. Celery which is banked in the earth often has the blanched stems marked by rusty spots of various sizes. These spots appear to arise from the contact of the stems with the earth, and on microscopic examination seem to be due to the fungi or bacteria, or both, that may be present in the soil. The difficulty is prevented by avoiding this method of blanching and substituting boards or close culture planting.

Bad Seed. There is scarcely a more vital question in celery growing than that of the quality of seed used. Seed that is of a bad strain though true to varietal name, may inflict losses of hundreds or thousands of dollars on large growers. Hollow celery, or that otherwise useless, according to present knowledge is very often due to the bad seed.

Fig. 40. Twig of cherry attacked by black knot. This is the summer condition when the conidia are numerous upon the surface and often give an olive color to the knot.

CHERRY

Black-Knot. This is a conspicusus disease attacking the branches of cherry and plum trees but is more frequent upon the cherry varieties of the Morello type. It is due to a parasitic fungus (*Plowrightia morbosa* Schw.). Insects, however, make harbors of the interior of the knots. The spores of the black-knot fungus are ripened during the winter and scattered in early spring, finding lodgement on the new branches or in fractures on old ones, where their growth causes the formation of a new knot. Black-knot may be prevented by spraying with Bordeaux mixture, but is more profitably controlled by carefully cutting off affected parts and burning them, making a clean sweep at least once each year and that *previous to March 1st.* This is a practicable measure and we have confidence in its efficiency.

Leaf-Spot and Mildew. The first named disease is caused by the same fungus (*Cylindrosporium Padi* Karst.) as that which we call "shot-hole fungus" on the plum, and may be successfully prevented by the use of Bordeaux mixture, except that only half the strength of mixture may be applied with safety to the foliage of the cherry. (See Calendar). The mildew is usually found chiefly upon sprouts

and young shoots. The mildew fungus (*Podospharva Oxyacanthae* (DC.) De By.) is a very interesting one. This applies especially to amateur microscopic study. If spraying is required for the mildew two applications will probably be very satisfactory.

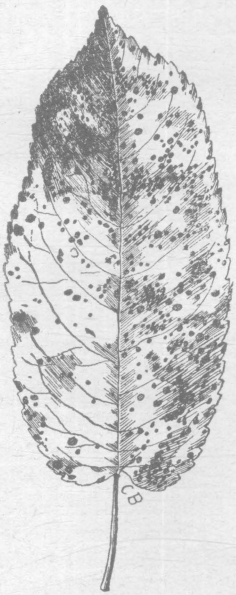


Fig. 41. Leaf of cherry attacked by leaf-spot fungus. The dead areas in cherry leaves turn dry and rarely give shot-hole effects. The same fungus occurs upon the plum. From Bulletin 79.

Cherry-Rot or Brown-Rot (*Schlerotinia* (*Monilia*) *fructigena* (ers.) Schw.) affects all stone fruits, including peach, plum, apricot, etc. It is by far the most serious and baffling of cherry diseases to the commercial cherry grower. The decay of the fruit is caused by the fungus named. The conditions of the season may favor or retard the spread and development of the fungus. The threads of the fungus (mycelium) survive in the rotted fruits, which may hang on the trees unless removed. Careful removal of all rotted fruit and spraying for the fungus, as per the calendar, may be relied upon to save a part of the fruit, but judgement and attention to the details of the work are always required. It is to be understood, also, that checking the curculio is a sure means of helping to check rot.

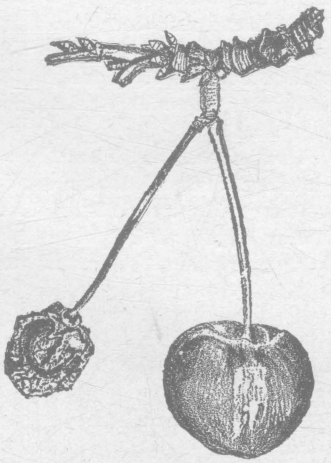


Fig. 42. Cherries, sound and rotted. The parasite in this case is the same as on other stone fruits.

CHESS

Anthracnose. The anthracnose fungus (*Colletotrichum cereale* Manns. attacks the chess as well as the cerea s in which it may grow. The disease is of interest upon chess because it may be a source of extending the development of anthracnose. (See anthracnose of oats, rye and wheat).

CHESTNUT

Anthracnose is a disfiguring spotting of chestnut leaves, about which inquiries are often made. Small, dead areas with characteristic borders are produced by this fungus (*Marsonia ochroleuca* B. & C.). Such applications of fungicides as are made for shot-hole fungus of the plum and leaf-spot of the horse chestnut, will be found useful when treatment becomes necessary on the chestnut.

Bark Disease. A serious bark disease of chestnut in the east has recently been described and has proved injurious. The fungus (*Diaporthe parasitica* Murr.) appears to enter as a wound parasite through openings in the bark. It has exterminated a part of the chestnut trees in the eastern half of I ong Island and about New York City. (See Yearbook, U. S. D. A., 1907, pages 489-490, also Bulletin, Bureau of Plant Industry, No. 121, 1908). The beginnings of the

disease show on branches with smooth bark, by the presence of dead, discolored or sunken patches sometimes covered with the yellow orange or brown pustules of the fungus.

CHRYSANTHEMUM

Leaf-Spot is frequently a disfiguring disease of this plant in earlier growth. It is caused by the leaf-spot fungus (*Septoria Chrysanthemi* Cav.). Two other fungi, a Phyllostica and a Cylindrosporium, also attack the chrysanthemum. For indoor treatment copper sulfate solution of one fourth of the strength given in the spray calendar—that is one pound to 50 gallons of water—will prove available. More applications will be required, but the foliage will not be rendered so unsightly as with Bordeaux mixture which, however, may be applied in full strength.

Powdery Mildew. Powdery mildew also occurs upon chrysanthemum foliage. The fungus (*Erysiphe Cichoracearum* DC.) is usually not persistent, but calls for spraying foliage with fungicides when serious.

Ray Blight. A blight of the rays of chrysanthemum flowers due to a specific fungus (*Ascochyta chrysanthemi* Cav.) is reported from the south and is very liable to be present in Ohio.

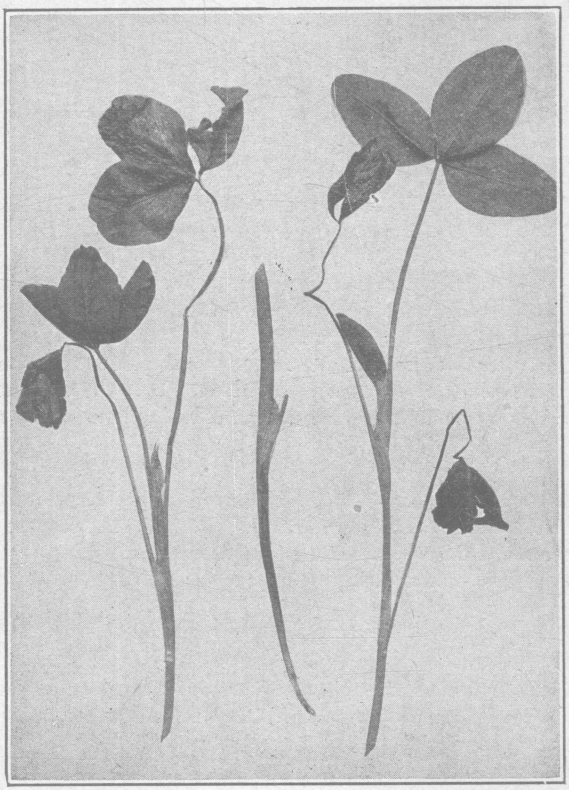


Fig. 43. This shows clover plants from fields at the Station attacked by new anthracnose fungus in 1909. This causes the leaves to droop and die; also at times the tips of the stems. From a photograph by T. F. Manns.

Rust. This is found on the chrysanthemum, resembling other rusts in its development. Rusted leaves and badly rusted plants should be destroyed.

CLOVER

Anthracnose. Three anthracnoses occur upon clover; the more common of which is due to the same fungus (*Colletocrichum trifolii* B. & E.) as the anthracnose of alfalfa. In 1907 it attacked the clover over the southern one-third to one-half of Ohio, causing dying of the plants attacked. These show lesions of the stems and leaf stalks and may be detected in the new seedings in late summer through the dying of the leaves of these plants. It is not known how serious this may prove upon clover, nor is this one known in northern Ohio.

The second anthracnose fungus (*Gloeosporium trifolii* Peck.) has been known longer than the first and occasionally shows by killing the tops of large

clover stems in meadows. It is apparently not a serious disease, although a very interesting one to study in connection with the anthracnoses due to Colletotrichum.

The third anthracnose upon clover (*Colletotrichum cereale* Manns.) is the anthracnose of wheat, rye and oats. It was found to a limited extent attacking clover upon the Station grounds in 1909. Except in microscopic characters this anthracnose cannot be distinguished from that of Bain and Essary first mentioned above. In the microscopic characters the two are clearly distinguishable. It is quite probable that this fungus will be found over much of the state.

Black-Spot is due to a fungus (*Phyllachora trilfolii* (Pers.) Fckl.) which attacks the leaves of clover causing dead spots and dark discolorations on the under side of the leaves. As a rule these attacks come so late in the working life of the leaves that the injury is slight.

Dodders occur upon clover as well as upon the alfalfa; with it, likewise, there are two species (*Cuscuta Epithymum* Murr. and *Cuscuta arvensis* Beyr.), the seeds of which are distributed in the clover seed. In 1907-8 when the domestic supply of seed ran so low the lack was made good by importations from Europe. This has brought a large amount of dodder into the state, the most of it being the clover dodder proper. With clover seedings as with alfalfa where infestations are slight it will pay to dig up by root the infested plants and burn them for destruction of possible seeds. Dodder is a parasitic twining plant and may be easily recognized by its appearance. The seeds are illustrated in Bulletin 175.

In the handling of the new clover seedings infested with dodder, it is probably best to clip in fall to prevent ripening of the dodder seeds. The hay crop may be cut the following season without fear since the seeds will not be in condition to grow. Following the mowing of the hay crop it is probably desirable to break the clover sod after the growth is fairly well started, and before time enough has elapsed to permit ripening of the dodder seeds. In no case is it desirable to cut seed from such dodder infested fields. Dodder in clover hay is held responsible for scouring of cows and horses.

Leaf-Spot. A leaf-spot of white clover referable to an anthracnose fungus (*Ascochyta* sp.) has been described from our region although not definitely determined in Ohio. The injury which may result cannot be now stated.

Rust. The various sorts of the cultivated clover, Red, Alsike, Mammoth, etc., are attacked by a clover rust (*Uromyces Trifolii* (A. & S.) Wirt). If one will examine the small, dark spots in the clover leaves he will find a cluster of this reddish fungus beneath. This rust does not spread to other plants than clovers and is commonly regarded as more disfiguring than destructive. It is not nearly so injurious as the leaf-spot of alfalfa which is similar in appearance.

Root Nodules and Root Tubercles upon Leguminosae. Upon removal of the roots of the clover plant from the soil one finds minute enlargements which are the subject of frequent inquiry. These are nodules or tubercles as they were formerly called, caused by the messmate-living of certain nitrifying organisms, or microbes, with the clover plant. To these microbes in this communal life is due the power of withdrawing nitrogen from the atmosphere and fixing it in the the tissues of the clover plants. The same applies in general to the nodules upon plants of this order, the *Papilionaceae*. It thus follows that these nodules are the normal condition of properly nourished leguminous plants of the order *Papilionaceae*, and it likewise follows that the full value of this work of nitrogen fixing is only realized for manurial purposes when the tissues of the clover plants decay in the soil.

Stem Blight of clover has recently been studied at the Station and has been found to be due to the same fungus as that of wheat scab (*Fusarium roseum* Lk.). This fungus has been found to cause the death of seedling wheat plants and to follow harvest by attacks on clover stems. (See Bulletin 203). It appears at this time to be one of the serious forms of clover sickness. The writer looks upon it as liable to be much more serious even than anthracnose. The only present suggestion for control will apply to control of the wheat scab fungus through recleaning of seed and separation of of all scab infected kernels. It is quite likely that clover seedings made in a dry year with little grain scab will not be exposed to the same danger from this blight as those made in wet seasons when the disease is very bad in the grain. (See wheat scab).

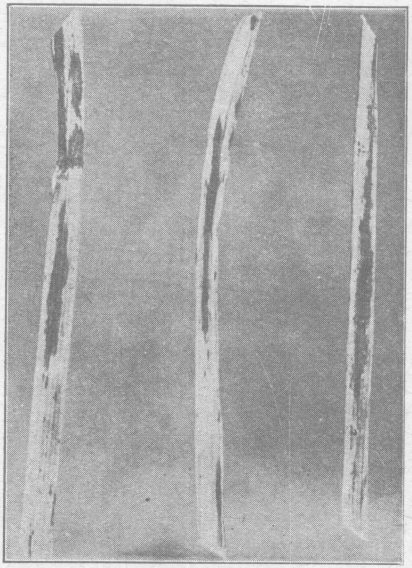


Fig. 44. Red clover stems suffering from stem sickness. The grayish spores in the lesions are those of the fungus of wheat scab. From Bulletin 203.

CORN

Bacterial Disease. This has been described and illustrated in Bulletin 6 of the Illinois Experiment Station, 1889. The malady infests both younger and older plants. In the younger it causes a yellowish coloring and a general appearance of debility, with death of the leaves, commonly from the point backward. After midsummer, spots appear on the exterior of the sheaths which are more conspicuous on the inner side and at times more or less smeared with a gelatinous substance. No successful remedy has as yet been proposed.

Dry-Rot or Mold. The dry-rot or mold of corn (*Diplodia zeae* (Schw.) Lev.) was investigated by this Station in 1906, it being reported by a grower in Licking Co. He stated that he had been studying the development for two years; the first time noted, the mold area was small involving but part of one shock; the next year a larger area had been invaded and the year of 1906 he reported his losses were still greater. He reported that conditions clearly indicate the invasion of the soil by the parasite and possible infection through the growing plant. As in this case from Licking county and many others in which continuous corn growing is practiced on rather moist soil, there is great danger from accumulation or infection. The ears attacked were marked by adherence of the husk and the uniform moldy covering matted the kernels together upon the ear and destroyed the feeding value.

In the matter of prevention little can be done beyond avoiding continuous cropping of corn for invaded areas. For life history of the fungus see Circular 117, Illinois Experiment Station; 22nd Annual Report, Nebraska Experiment Station, 1908.

The Leaf Blight Fungus (*Helminthosporium graminum* Rab.) has been noted on corn and has recently been sent to this Station from Vinton county, in the latter case upon sweet corn. The fungus causes somewhat extended, or elliptical

brown (dead) areas in the leaf blades, readily identified by the microscope. All diseases of the young corn attract notice, but it is not certain that there is need to apply fungicides for this fungus, though such might prove successful.

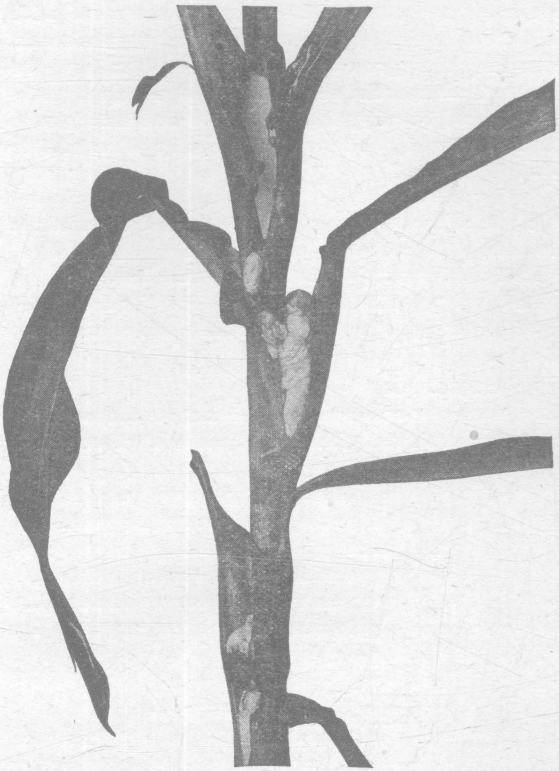


Fig. 45. Stem of maize attacked by smut. The smut boils shown here later burst open and scatter masses of smut spores.

Corn Rust (*Puccinia Maydis* Berang.) is met with in greater or less abundance upon corn every season, the greater abundance usually being in rainy seasons. The rust causes small oblong or elliptical spots on the surfaces of leaf and sheath and in the spots are contained reddish-brown spores of the rust. The shade of the spores will vary with the time and development of the fungus. Here, as with wheat, the fungus passes through the uredo and teleuto stages.

Silage Mold. At times we have complaint of mold in silos where corn silage is stored. Doubtless there is some loss in nearly all cases from different molds or decays where the air circulates in contact with silage. We have investigated the mold fungus (*Penicillium* sp.). This is possibly the same blue mold which we have found to attack fruits in storage and transit. It is not an active organism and must be held in check by control of conditions in the silo.

Fig. 46. An ear of corn partly destroyed by smut, Other ears may be found showing different forms of attack.

Corn Smut is a well known disease, attacking leaves, shoots, ears, tassels and brace-roots of corn, converting the diseased parts into masses of dirty (smutty) spores of the fungus (*Ustilago Zeae* (Beckm.) Unger). A brief article upon corn smut will be found in Bulletin 78. (See also Bulletin 92 of the Kansas Experiment Station). The corn smut may be propagated by smutty seed, although much more likely to be carried by the transportation of the yeast spores of this smut fungus which may light upon any young growing part and produce smut infection. From this fact and from another—probably a greater

prevalence of the smut yeast spores in later summer—later growing parts, for example, tassels, brace-roots, ears and sucker shoots, are perhaps more often attacked by the smut. The smut spores may be scattered in manure if smutted fodder is used, and it seems well proved that manured land yields more smutted corn than unmanured. The same may be true of clover sod as compared with corn stubble. The reason would exist in the decayed vegetable matter, wherein the secondary yeast spores of the smut may grow and then may be carried to the corn which becomes thus affected. Treatment of seed corn does not apparently reduce the amount of smut. Cutting and burning the smut boils before they have burst open would be useful. It is worth while to fight smut by all available means.

COWPEA

Leaf-Spot. In southern Ohio where these are grown there is danger of the leaf-spot (*Cercospora*). This is not liable to be very serious.

Wilt. The wilt fungus (*Necosmospora vasinfecta tracheiphila* Erw. Sm.) is more serious, although at present largely confined to the southern districts. For Ohio conditions the practice of growing cowpeas is not of such extent as to threaten seriously with this disease.

CRABAPPLE

Scab. The same scab which attacts the common cultivated sorts also attacks the crabapple, including both fruit and foliage. The remedy is that given under apple.

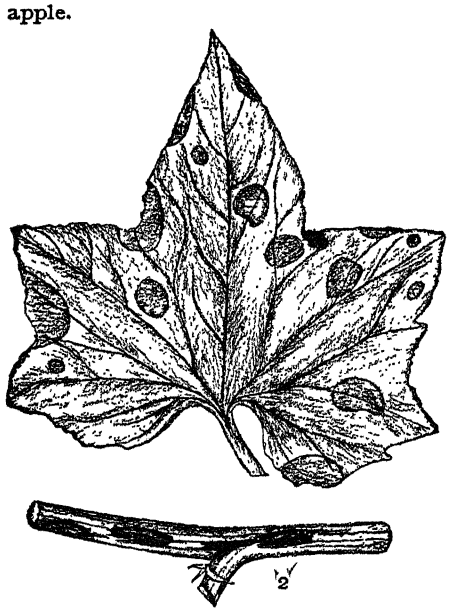


Fig. 47, Cucumber leaf and stem attacked by Anthracnose. The dead areas in the cucumber leaf, caused by Anthracnose, are usually larger and more nearly circular in outline than with downy mildew.

Rust. The same rust fungus (*Gymnosporangium macropus* Lk.), in the cluster cup stage appears on the crabapple leaves and fruit as well as upon the leaves and fruit of apple, and leaves of crataegus. (See Apple).

CROCUS

Root-Rot. Little study has been made with us of the diseases of bulbous plants, yet we are liable to import those occurring in Europe. The common root infesting fungus, *Rhizoctonia*, is one of the determined troubles of crocus in France. Microscopic identification of the trouble should be easy owing to the characters of the fungus.

CUCUMBER

Anthracnose (*Colletotrichum Lagenarium* (Pass.) Hals.). This fungous disease attacks nearly or quite all curcurbits as well as the bean. Upon the cucumber in Ohio it is apparently more destructive during the earlier season. The fungus may be found in the greenhouses at all cultural periods, as well as in the field. It causes circular dead spots in the leaves, usually more than one-fourth inch in diameter, and likewise elongated brown areas on the stem. (See Bulletin 73, 89 and 105)

Unlike the downy mildew, anthracnose may be checked after it appears, though best prevented by earlier applications of the fungicide. In the field, Bordeaux mixture is to be preferred; in the greenhouse, copper sulfate solution, one pound to 50 gallons, has proved efficient and has checked the anthracnose after one-fourth of the plants had been destroyed by it.

Damping-off is a frequent trouble upon greenhouse cucumbers. It is serious often where plantings are made following lettuce attacked by rosette. The fungus in that case is the same as lettuce rosette (*Rhizoctonia*) or lettuce drop (*Botrytis*). There is a strictly damping-off fungus (*Pythium De Baryanum* Hesse) that is sometimes troublesome. The Botrytis named at times attacks pruned parts of cucumber plants, also extending its attacks to the blossom end of young fruits.

The results of Rhizoctonia on greenhouse cucumbers have been curious owing to attacks on the smaller root branches or rootlets. The growth of the vines is at times checked, accompanied by coloring of the leaves and reduced fruitfulness. Some growers have given the name "leaf-curl" to this phenomenon but it is strictly the effect of the fungus named. It has been found necessary in soil treatments where cucumbers follow affected lettuce to increase the strength of formalin drench to 4 or 5 pounds per 50 gallons of water. (See Soil Diseases).

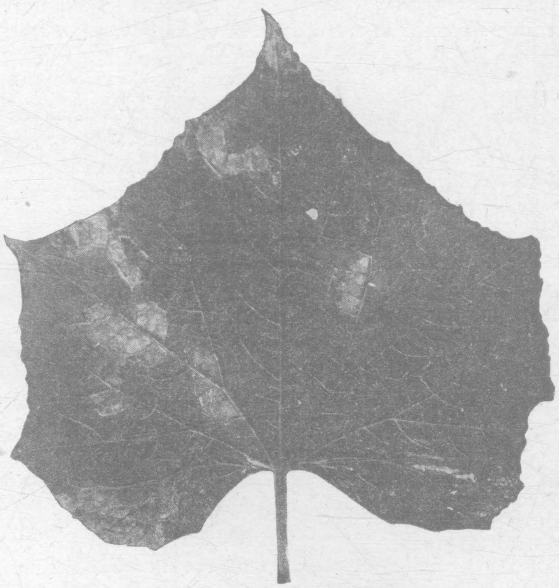


Fig. 48. Cucumber leaf from greenhouse, attacked by Downy Mildew. The spots in the leaves caused by the mildew are usually outlined by the veinlets of the leaf.—From a photograph by T. F. Manns.

Downy Mildew. Downy mildew fungus (*Plasmopara Cubensis* (B. & C.) Humph.) is late in its attacks, not having been found in Ohio fields earlier than August 3rd. It causes angular, yellowish spots on the leaves, followed by yellowing of the whole leaf and death, as by frost. It spreads with extraordinary rapidity, requiring only three or four days to become disseminated throughout a large field. Unlike anthracnose, it may not be successfully checked after its appearance, and it is not safe to leave untreated plots in fields to be sprayed. July 25th to August 1st is sufficiently early to begin spraying for mildew, but applications should be repeated at intervals of 7 or 9 days. In 1898 an increase of 75 bushels per acre, of sprayed over unsprayed cucumbers, was obtained at Creston. (Bulletin 105). Cucumber pickle growing finds in this mildew its most serious enemy. If any of the crop is to be harvested after August 20-25 spraying with fungicides appears necessary. Early planting may permit gathering the crop before this date. The downy mildew is also very destructive in the forcinghouse, and is to be treated with the same fungicides recommended for anthracnose. (Bulletins 73, 89 and 105).

Leaf-spot of cucumber is also due to fungi. (*Phyllosticta Cucurbitacearum* Sacc. and *Cercospora Cucurbitae* E.&E.) Of the two species named, the Phyllosticta was the commoner in thrifty pickle fields in 1898; the Cercospora being apparently confined to wet fields, though this cannot be expected to hold true under all circumstances. The Phyllosticta was found almost exclusively upon the unsprayed pickle plants and seems, therefore, amenable to the same treatment as applied for downy mildew. (Bulletin 105).

Mosaic Disease of greenhouse cucumbers has been recently studied in Ohio. This disease is analagous in character to the mosaic disease of tobacco and tomatoes and to the yellows of the peach. It is due to an oxidizing ferment in the leaves and is transmitted like the tobacco mosaic disease, by touching first diseased and then healthy plants. The fruitfulness of these variegated yellow plants is very low and it is best at all times upon the appearance of the disease to remove the diseased plants and destroy them.

Nematodes or Eelworms (*Heterodera radicicola* (Greef.) Mull.). These minute parasitic worms are often very destructive upon cucumbers under glass. They are especially so in some cases recorded in Bulletin 73. The greatest injury may occur on the seedling plants, but plants of all ages are destroyed by the parasitic worms. Their presence may be known by the small, bead-like enlargements produced upon the roots or rootlets. This matter is treated at some length in that Bulletin. No remedy has been discovered that is effective with plants once attacked by eelworms. The time to prevent this trouble is in the selection or preparation or treatment of the the soil for greenhouse benches. Indeed the nematodes seem to be present in old sod, and to some extent in decaying vegetable matter generally. An effective remedy against eelworms consists in steaming and so treating the soil that the parasites will be destroyed. For this procedure see calendar and Bulletin 73. Also Massachsetts Exp. Sta. Bul. 55, In thus handling the soil due time must be given for draining and drying.

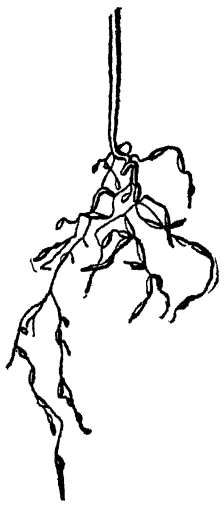


Fig. 49. Roots of seedling cucumber with Nematode galls upon them. These cause collapse of the plants.

Powdery Mildew (*Erysiphe Cichoracearum* DC.) of cucumbers is also frequent in the forcing house, but rarely destructive elsewhere. For this fungus a dilute copper sulfate solution is effective. See Bulletin 73.

Root-Rot. The root-rot or so-called "leaf-curl" development on matured cucumber plants referred to *Rhizoctonia*, is often serious. It is more fully discussed under damping-off above.

Spot of Cucumber Fruit or Cucumber Scab (*Cladosporium cucumerium* Ell. & Arth.), has been reported upon cucumbers by Dr. Arthur (Ind. Exp. Sta. Bul. 19), and may prove injurious if prevalent. It should be found amenable to the same treatment recommended for anthracnose and downy mildew.

Cucumber Wilts. The wilt diseases of cucumbers, likewise of other cucurbits, are a source of usual complaint in the earlier season, as the plants are beginning to form vines. In 1899 these complaints continued much later. The plants suddenly wilt down as from lack of water, then soon die. What has been referred to the same general cause was also observed in the cucumber forcing-house, apparently starting in the leaves. Smith (Proc. Am. Ass. Adv. Sci. 1893) refers this disease to a bacterium (*Bacillus tracheiphilus* Smith) which is transferred from diseased to healthy plants by the cucumber beetle and the squash bug. This form of wilt has been found on cucumbers, muskmelons and squashes

in Ohio. In addition we have found to a limited extent, another wilt disease of the cucumber which appears to be similar to that described by Dr. Smith. (Proc. Am. Ass. Adv. Sci. 1895, p. 190). On watermelons in the South he finds a trouble with which ours may be identical. (Bul. 105, p. 222). This latter is referable to a species of fungus, a fusarium (*Fusarium niveum* Smith), which grows internally in the stem and finally plugs up the water vessels in a manner similar to the work of the bacterial wilt. Spraying is unlikely to be beneficial for this wilt or for the bacterial one. Preventive measures suggest gathering and burning infected vines, and especially waging a successful war against the insects; these should prove more or less successful according to thoroughness of work. The fusarium wilt calls for rotation of crops. Much may be finally done by breeding varieties resistant to wilt.

CURRANT

Anthracnose. The anthracnose (*Gloeosporium ribis* (Lib.) Mont.) of the currant has occurred occasionally and will apparently be checked by the same treatment as given for raspberry anthracnose.

Cane Blight is a very serious disease whenever stools are attacked by it. The fungus (*Nectria cinnabarina* (Tode) Fr.) survives by its threads in the tissues of the stool and upon the dead of the canes develops as a bright pink mass of the fungus upon dead parts. While spraying may, and surely must, keep down the risk of infection, whenever stools show attacks by dying of a part of the canes and the development of this fungus these infected stools are doomed and should be removed and burned.

Black-Knot. A black knot fungus (*Plowrightia ribesia* Pers.) has been described upon currant, and is always a possibility with us. It attacks the branches or stems.

Dropsy. This disease has been met with. It causes very considerable enlargement upon the young stems of the currants, not unlike in appearance the enlargements due to crown gall in the peach, except that usually more of the stem is involved than in the other case. The trouble appears to be due to physiological causes and the pruning knife may aid cultural efforts.

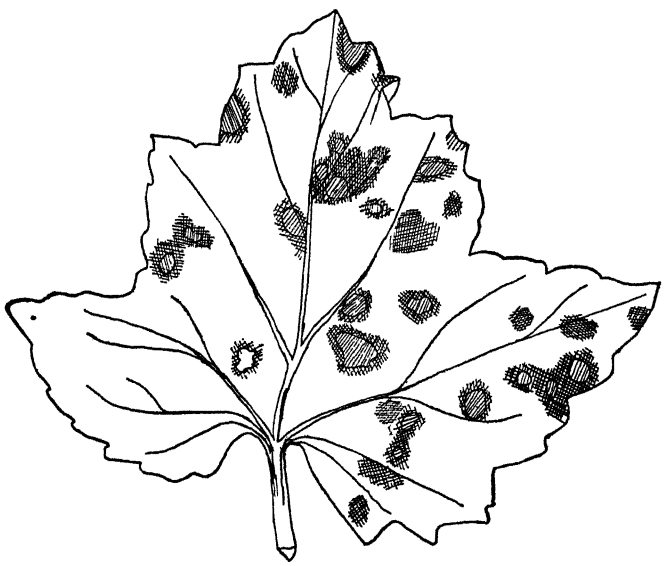


Fig. 50. Leaf of currant attacked by leaf-spot. The dead areas are easily seen in the currant leaf but the fungus is difficult to discover

Knot. This fungus (*Pleonectria berolinensis*, Sacc.) is a stem trouble of currants and calls for investigation. It has been collected in this state.

Leaf-Spot of currants is referable to two species of fungi (*Septoria ribis* Desm.; *Cercospora angulata* Wint.) of which only the Septoria has been discovered in Ohio. (See Bulletin 79). These fungi produce early spotting and premature dropping of the currant foliage; in some instances the leaves drop even before the fruit has ripened. Bordeaux mixture applied as per calendar is effective against this disease, though late applications may render it necessary to wash the fruit. For this reason, if for no other, the first application should be made very early and followed by about two more at fortnightly intervals.

Rust. A rather common rust fungus (*Puccinia ribis* DC) has been discovered upon currant. Warning has been recently sent out against a second fungus (*Cronartium ribicolum* Dietr. *Peridermium strobi* Kleb.) which attacks the seedlings of white pine in the aecidial stage, and passes its uredo and teleuto stages *upon leaves of currants and gooseberries.* This fungus is to be sought for with care since its occurrence in the United States may have much to do with the success of forest plantings of white pine.

Powdery Mildew of gooseberries (*Sphaerotheca mors-uvae* (Schw.) B.&C.) sometimes attacks currants where it is apparently less destructive than on gooseberry. Reasonable spray treatments should control it.

DEWBERRY

Leaf-Spot. (*Septoria rubi* West.) Cultivated dewberries as well as the wild sorts, are peculiariy susceptible to the attacks of the leaf-spot fungus. It causes very small grayish spots in the leaves. The same fungus attacks blackberries and raspberries, as previously stated. It may be prevented by a careful application of Bordeaux mixture.

Rust. The bramble rust also attacks the dewberry as in the case of blackberry. For treatment see blackberry.

EGG-PLANT

Anthracnose. The anthracnose fungus of egg-plant (*Gloeosporium melongenae* Ell. & Hals.) attacks the fruits of egg-plant and causes spots in them. This occurs frequently in Ohio. These show early as pits in the surfaces of the fruit which show the usual border.

Bacterial Blight. The common solanaceous blight organism (*Bacterium solanacearum* Erw. Sm.) attacks the egg-plant as well as the potato and tomato. Where attacks occur destruction of the affected plants is all that can be done.

Fruit-Rot. A fruit-rot of egg-plant likewise occurs and may at times appear as a leaf-spot fungus. This, like the anthracnose and leaf-spot, should yield to treatment by sprays. Ammoniacal copper carbonate may be used toward the ripening period.

Leaf-Spots. Two or more leaf-spot fungi have been recorded on egg-plant and will doubtless be found when sought.

Stem-Rot. The stem-rot fungus of sweet potato (*Nectria ipomoeae* Hals.) has been described upon egg-plant by Dr. Halsted. The conidial stage is evidently a species of fusarium and it may or may not be a different one from that with which we have to contend upon the potato; it is recorded by Dr. Halsted as the same that occurs on sweet potato.

ELM

Bleeding. Bleeding of pruned elm trees is often annoying as well as dangerous. Mr. Boddy, City Forester of Cleveland, thinks asphaltum covering over cut surface reduces or cures the bleeding. This is successful when searing by torch precedes application of dressing.

Black-Spot. The leaves of ornamental elms are attacked by black spots (*Dothidella ulmi* (Duv.) Wint.) (*Gnomonia Ulmea* (Sacc.) Thuem.) which sometimes injure the leaves, and by this means checks the tree.

Other Leaf Diseases also occur upon the elm. One of these is a leaf-spot (*Phyllosticta ulmicola* Sacc.) which matures its spores in the fallen leaves. Gathering and burning these infested leaves will prove a check on this fungus.

The Powdery Mildews (*Microsphaera Alni* D.C. and *Uncinula macrospora* Pk., more often the latter) likewise attack elm leaves. If troublesome these should be reached by applications of Bordeaux mixture, making the first application when the leaves are half grown.

Timber-rots are also known on the elm; to be guarded against in wound infection of shade trees.

Twig Disease. In portions of Ohio and in Kentucky a dying of elms which are prized as shade trees has been reported. This disease shows first as a loss of leaves at the ends of twigs, often at the tops of trees. (See Kentucky Exp. Sta. Bul. 84). It is believed by Prof. Garman that changing soil conditions have much to do with this disease. To the writer it would seem that the water factor with this, as with many other shade trees, may prove a determining cause. At any rate, the time has come for a study of these water problems in shade trees.

EMMER

Anthracnose, Scab, etc. Emmer and its near relative, spelt are attacked in Ohio by the Anthracnose (*Colletotrichum cereale* Manns) and by the scab (*Fusarium roseum* Lk.) These diseases are the same as those occurring upon rye, wheat and other cereals under which heads fuller notes will be given. (Also see bulletin 203).

FIG

Leaf Diseases. The fig is frequently grown in conservatories and is often attacked by leaf diseases. The commonest leaf fungus (*Cercospora Bolleana* (Thuem.) Speg.) of the Mediterranean region is a serious leaf disease. The attacked spots assume a brown color, the leaves eventually yellowing and dropping off. Where leaves of fig begin to drop from such causes, a spraying with Bordeaux mixture should be applied upon the younger leaves.

FILBERT

Black-Knot (*Cryptosporella anomala* (Pk.) Sacc.) has been found upon cultivated filbert or hazel-nut in New Jersey and Massachusetts (N. J. Exp. Sta. Rept. 1892 and Mass. Exp. Sta. Rept. 1892). This is a serious stem disease which may check successful culture when it occurs.

FLAX

Dodder. Flax is attacked at times by a seedling parasite, flax-dodder (*Cuscuta Epilinum* Weihe) whose tiny, leafless stems wind about the flax plant and by haustoria, or sucking organs penetrating the epidermis, draw from it substances essential to healthy growth. The dodder seeds are carried in the flax seed and prevention must seek to avoid the seeds.

Other Diseases of flax are noted to occur in the Northwest among which are a Fusarium wilt and a Colletotrichum blight. (See bulletins 50, 55 and 71, North Dakota Exp. Sta.).

FOREST SEEDLINGS

Forest seedlings as will be noted under Catalpa, Pine and Spruce are especially liable to certain disease attacks upon the young plants. The number and variety of these diseases is scarcely realized until one begins to care for their survival as in forest culture. It will usually be found in newly cleared areas used for this purpose that the leaf mold is badly infected with seedling parasites. Some treatment of this soil before using as seed beds is desirable. For some of the commoner damping-off fungi the formalin drench may succeed. For coniferous seedlings, other treatments may be required. Recently the United States Department of Agriculture has reported upon two methods of treatment which consist of the use of dilute sulphuric acid, or mixtures of lime with powdered copper sulfate. (See circular No. 4, Bureau of Plant Industry, United States Department of Agriculture).

GINSENG

Leaf Blight or Leaf-Spot, (*Alternaria* sp.) occurs upon ginseng plantations. These have been checked at times by spraying with Bordeaux mixture, while at other times the sprays being made immediately before cold weather caused serious losses.

Root-Rot. The root-rot fungus (*Thielavia basicola* Zopf.) has been found in New York by Van Hook to attack the roots of ginseng and cause destructive rotting. This may prove a serious drawback to ginseng growing, and methods of prevention are difficult to propose. (See Cornell Exp. Sta. Bul. 219).

GOLDEN SEAL

Leaf-Blight of golden seal occurs in many plantings. It is due to a fungus of the same genus (*Alternaria*) that proves troublesome on leaves of ginseng. Spray applications need to be worked out for it.

GOOSEBERRY

Leaf-Spot. The gooseberry leaves are attacked by the same leaf-spot fungus recorded upon the currant (*Septoria ribis* Desm.), although the defoliation may be even more severe than on the currant. In spraying experiments at this Station, conducted by the Horticulturist, it has been found that the gooseberry leaf-spot is more easily prevented than the currant leaf-spot. Indeed no fungus disease upon which we have experimented is more easily prevented when the fungicide is applied at the proper time. (See Spray Calendar). Often the leaves from gooseberry plants have all dropped before maturity of fruit, and in hot weather all the fruit has been lost on the unsprayed, check plants, while the sprayed plants gave a fine yield of satisfactory fruit.

Powdery Mildew (*Sphaerotheca mors-uvae* (Schw.) B. & C.) is a destructive fungus disease especially common upon English varieties, such as Industry, Crown Bob, &c. It has been destructive also upon the Houghton. As already stated this mildew attacks currants. From the nature of this fungus the first spraying with Bordeaux mixture should be made early in the season. (See Bulletin 79). Subsequent applications may be either of Bordeaux mixture or potassium sulfid. (See Calendar). After fruit is half grown the latter fungicide is to be preferred since it is more easily removed from the fruit.

Rust. See currant rust.

GOURD

Anthracnose, Downy Mildew, &c. Gourds are susceptible to the same fungus diseases as the cucumber. The two most conspicuous are anthracnose and downy mildew. The anthracnose, especially, causes spotting and discoloration on the gourds. This may be arrested if, when the gourds are gathered, they are subjected to treatment with scalding water; otherwise the development of the fungus continues while the disfiguring increases. Field treatment in this case is the same as recommended for like diseases of the cucumber.

GRAPE

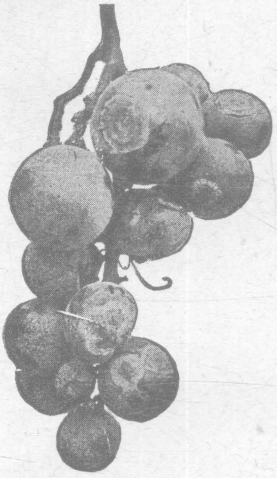


Fig. 51. Grapes attacked by anthracnose, also called Bird'sEye Rot.

Anthracnose. As is well known we have a long list of fungi attacking the grape, among them the anthracnose fungus (*Sphaceloma ampelinum*) which is found upon leaves and stems as well as the fruit, causing definite sunken spots, usually with a central area of lighter color. Upon the fruit the appearance has suggested the name "bird's-eye-rot" and the last the name bitter-rot. Where prevalent the anthracnose may be entirely prevented by following the directions in the use of Bordeaux mixture as given in the calendar.

Bitter-Rot (*Melanconium fuligineum* (Scrib & Viala) Cav.) of the grape is sometimes prevalent but perhaps less frequent in Ohio than the black-rot.

Black-Rot (*Guignardia Bidwellii* Ell.) is one of the most troublesome and destructive of grape diseases. It chiefly attacks the fruit and causes dark spotting and rotting of the green berries, but it may also attack the leaves, petioles and cluster branches, producing circular or elongated dead spots in them. The rotted fruits persist upon the branches and may hang on over winter, thus carrying the fungus from year to year. This disease, if neglected, is very destructive and the longer the neglect the greater is the difficulty in prevention. Because of the circumstances stated, delay in beginning the treatment increases the difficulty. It is apparently essential that first applications of fungicide for the black rot be made while the vines are dormant and that these be very thorough, followed by the later applications as per calendar. Omission of the spraying just before the blossoms open may lead to ragged clusters, from dropping of the small grapes. (See report of the U. S. Dept. of Agr. 1896). (Ohio Exp. Sta. Bul. 130).

Fig, 52. A cluster of grapes attacked by Black-rot. The rotting grapes are light brown in color immediately following decay.

Crown-Gall. Crown gall of the grape is known to give trouble in Ohio. This comes as enlargements near the crown and on the roots. The latter occurring upon raspberry, peach, etc. It is believed to be due to the same cause as the other crown galls and to be handled only through removal

Downy Mildew (*Plasmopara viticola* (B. & C.) Ber. & D'Ton) of the grape is a prevalent fungus disease which has long been known and repeatedly studied. By it the leaves are attacked and the fungus forms in them öospores by which the winter is passed. The fungus also attacks the berries, causing brown-rot. Gathering and burning the fallen leaves may therefore be useful. No particular difficulty attends the prevention of downy mildew if spraying is thoroughly done.

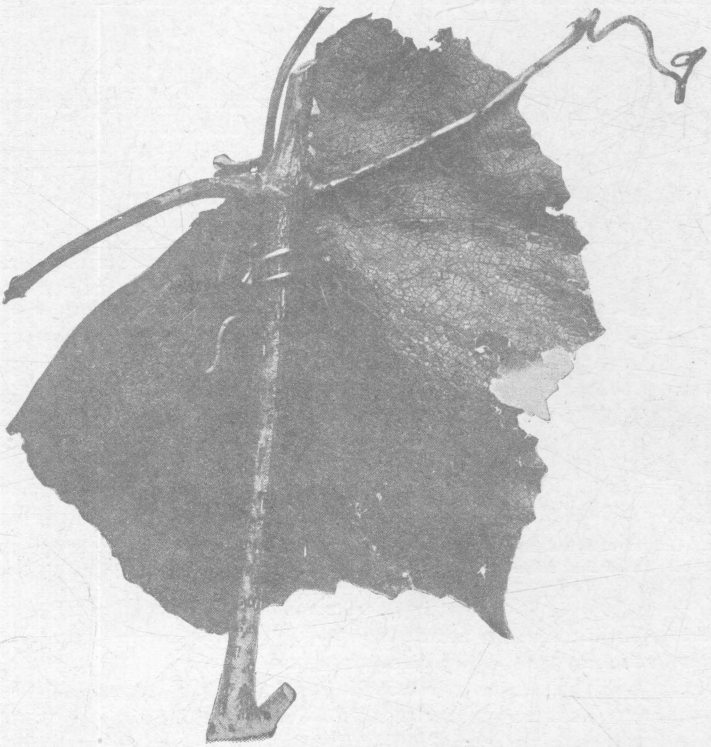


Fig. 53. Leaf and stem of grape attacked by Black-rot. The lesions in the stem are dark colored. Those in the leaf show as dying areas.

Powdery Mildew (*Uncinula necator* Schw.) is likewise prevalent upon both leaves and fruit. Like all powdery mildews the parts attacked are covered over by the web-like threads of the mildew fungus. This is successfully prevented by the use of Bordeaux mixture as elsewhere directed. (For illustrations of grape diseases see Report U. S. Dept. of Agriculture 1886 and 1887; also Scribner, "Fungus Diseases of the Grape, etc.").

Stem Cankers. Stem cankers of the grape are rather frequent. Many of these are due to injury caused by freezing by which dead spots are produced and in the process of healing these injuries become surrounded by excessive growth and enlargements. In some instances the enlargements obtained a diameter of two or three times the size of the stem. The preventive measures are the same as for any freezing injury, viz., drainage and prevention of excessive late growth.

Dying of grape canes has been studied in one vineyard where it appears also to be associated with crown gall and to result from other diseased conditions. (See circular 64). In this case a portion of the vineyard died out almost completely; followed by sprouting of a portion of the roots. In August there was wilting and drying up associated with diseased stem conditions.

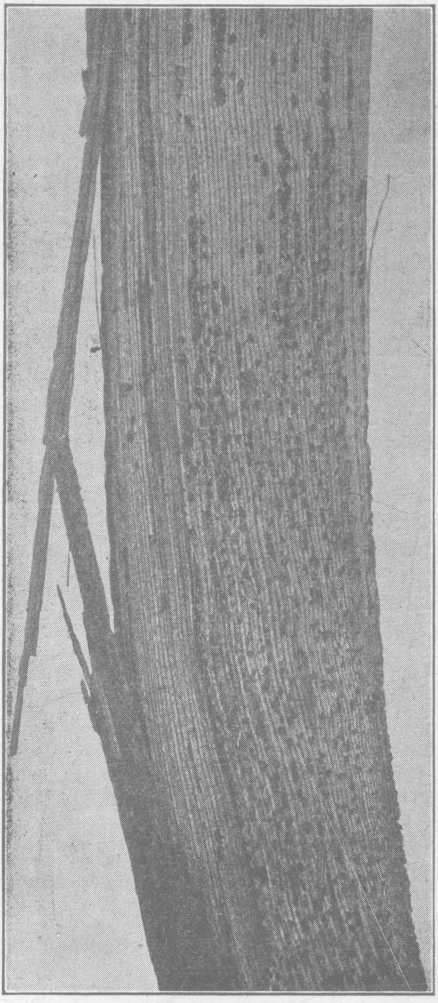


Fig. 54. Illustration showing stroma of a fungus believed to take part in death of grape stalks. The separate dot-growths are at times united into elongated ridges. From Circular No. 64.

The history of this case indicates that the removal and replanting of vines will be more successful than to endeavor to start vines again by sprouts from bases of injured vines.

White-Rot. Diseased conditions of the earlier stages of black-rot showing light color of the berries leads to the use of the term white-rot. As yet, however, the writer has never conclusively proved that we have a white-rot development different from this stage of the black-rot of the grape in Ohio. Where growers suspect this form of rot the method of treatment is the same as for black-rot.

GRASSES

Anthracnoses, Smuts and Rusts are found upon the grasses. These are in part described under blue-grass, orchard-grass, red-top, timothy, and chess.

HAZELNUT

See Filbert.

HEMLOCK

Hemlock grows freely with us and is apparently quite free from foliage troubles.

Heart-Rot (*Trametes pini* (Brot.) Fr.) and Sap Rot (*Fomes pinicola* (Sw.) Gill) are reported from districts where special attention is given to the conditions.

HICKORY

Leaf-Spot. A hickory leaf-spot (*Marsonia juglandis* (Lib.) Sacc.) is quite general and leads to dying of the leaves prematurely. This really merits much closer study than has yet been given it in our state.

HOLLYHOCK

Anthracnose (*Colletotrichum malvarum* (Braun & Casp.) Southw.) An illustration has been published in the Journal Mycology (Vol. 6:46-48). It may attack any part of the plant, and is a serious trouble where it occurs.

Leaf Blight (*Cercospora Althaeina* Sacc.) is another fungus disease of the hollyhock. These two diseases of the hollyhock should be amenable to spraying with standard fungicides.

Rust (*Puccinia malvacearum* Mont.) On the other hand this recently introduced disease of the hollyhock is much less likely to be prevented by spraying. The rust fungus forms dense patches, spots or sori, on the under side of the leaves. These are commonly about one-sixteenth inch or more in diameter, of grayish-brown color and projecting below the leaf surface, while a minute yellow spot early appears on the upper surface of the leaf. Subsequently the diseased leaves drop and by the time the plants are blooming the the stem below is bare or disfigured by the remains of the diseased leaves. At the Station this rust has been prevalent and the complaint is general respecting the same trouble. It would seem wise to gather and burn all the affected leaves and likewise the old stems as early as possible. Between anthracnose and rust these popular old flowers are having, at present, a difficult time of it.

HORSE-CHESTNUT

Leaf-Spot of the horse-chestnut (*Phyllosticta paviae* Desm.) is quite frequent. During 1908 and 1909, tip-burn was associated with leaf-spot; as near as could be determined, the tip-burn followed punctures of leaf hoppers or other insects and the plants made very restricted growth during the season. It may be necessary to take combined spraying applications for leaf-spot and the insect troubles. Bordeaux mixture is recommended for this purpose and has in the past given very satisfactory results for leaf-spot. The first application should be made when the leaves are about half grown, to be followed by others at intervals of three weeks.

HORSERADISH

Leaf Blight (*Ramularia armoraceae* Fckl.) is frequent upon horseradish and is also found upon other mustard plants. Ordinarily the severity of attack does not call for spray treatment.

Leaf-Spot (*Cercospora armoraceae* Sacc.) is less frequent and not serious in its effects.

White Mold (*Cystopus candidus* Pers) which is so common upon shepherd's purse and other low plants of the mustard family, likewise attacks horseradish. Owing to the heavy root development of horseradish the temporary parasitic attack does not give noticeable injury.

HYDRANGEA

Leaf Blight. A leaf blight fungus (*Phyllosticta Hydrangeae* E. & E.) has been observed on Hydrangea by Dr. Halsted in New Jersey. This may be serious at times upon this ornamental plant.

Rust. Hydrangea is likewise attacked by the rust fungus. (*Melampsora Hydrangeae* DC.) This may also be at times, quite serious. Remedies for neither of these troubles have as yet been worked out.

IRIS

Bulb-Spot. Massey has reported a fungus causing black patches on the surfaces of iris bulbs. This fungus (*Mystrosporum aductum* Mass.) from a description given, resembles onion smudge in its appearance and effects. Loss is prevented by soaking the bulbs for an hour in Formalin solution.

Leaf-Blight. The leaves and roots of iris have been reported in England to be attacked by a fungus. (*Botrytis galanthina* Mass.) This disease is likely to be present in shipments of iris about the world. It is described as first attacking the leaves and later destroying the root, thus causing the death of the plant.

IVY

Leaf-Spot and Leaf-Blight. Leaf diseases of English ivy are occasionally reported but have not been studied for our district. Dr. Halsted has described a blight upon variegated forms of English ivy (*Vermicularia trichella* Hals.). In this connection we need to bear in mind that variegated plants are especially susceptible to disease and are therefore liable to suffer.

JAPAN CREEPER

See Virginia Creeper.

LARCH

Canker and Rots. Larches are but little grown in our territory. In Canada there has been described a larch canker (*Peziza willkomii* Hartig.) This attacks the trunk and branches. In common with other conifers the larch suffers from tree infecting rot fungi. The lack of American data upon these diseases emphasizes our need for such studies.

LEMON

Greenhouse specimens of lemon trees are a source of a good many inquiries. These are chiefly leaf diseases which arise from the brown molds and other fungi infesting these plants. As a rule they are amenable to spray treatments with standard fungicides.

Rots. Allusion has been made to storage and transit rots of citrus fruits. The lemon is no exception to the attacks of these rots. The blue mold (*Penicillium*) is a very common form, and may be met with in almost any of the ordinary shipments of lemons. Brown-rot (*Pythiacystis citrophthora* R. E. Sm.) is a serious trouble in California lemons especially. It appears as a white mold on the surface of affected fruit.

LETTUCE

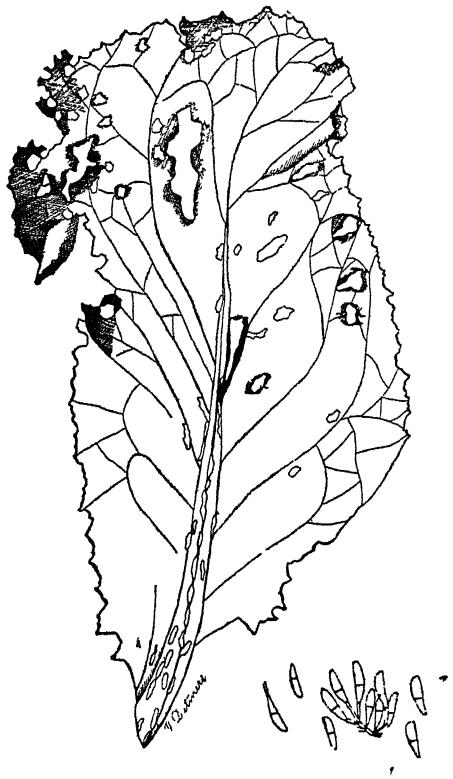


Fig. 55. Lettuce leaf attacked by Anthracnose. The dead spots caused by this fungus frequently break loose and drop out, causing perforation of the leaves. On the midrib the lesions are deep-seated. The two celled spores are shown highly magnified. From Bulletin 73.

Anthracnose or Leaf Perforation. This disease of lettuce was discovered by the writer in 1896 and sent to Dr. J. B. Ellis for description of the fungus (*Marsonia perforans* E. & E.) It shows upon the lettuce plants as dying of spots in the leaves which break free and drop out. The fungus also produces lesions in the midrib of the leaf. In cases of young leaves the attacks of the fungus causes distortion of the leaf, especially toward the top. Apparently very few plants recover after being once attacked, although one may reasonably keep down this disease in the seed beds and young plants by the use of Bordeaux mixture. For houses once seriously infested, thorough fumigation and soil treatment would probably be profitable. It is not generally distributed.

Downy Mildew (*Bremia Lactucae* Regel) is the work of another fungus which belongs to the same class as the downy mildew of the cucumber. It forms yellow spots in the upper leaf surface which appear below as whitened, downy covered areas. Like the downy mildew of cucumbers this one may spread very rapidly under favorable conditions, such as warmth and surface watering in the greenhouse. Keeping water from the foliage by sub-irrigation of the beds has been found very beneficial (Bulletin 73). Gathering and burning the diseased leaves or plants will usually repay the labor. Particular attention to heat and moisture will usually render spraying unnecessary and it is certainly inadvisable except to eliminate the fungus from the house. Avoid too high temperature or too much moisture on plants.

Rosette or Rhizoctonia. This is a very troublesome disease of greenhouse lettuce which arises from the accumulation of the sterile fungus (*Rhizoctonia* sp.) in heavily manured soils used for continuous greenhouse culture. Upon the young seedlings the Rosette fungus produces stem lesions and rotting off or damping off of the plants (Fig. 57) or with larger plants which are later attacked upon the branch roots or rootlets, the restricted root development prevents growth of the plant axis and gives a basal development of normal leaves with a rosette-shortened center of leaves. Where serious, the crop is shortened very much and

the loss of stand on smaller plants is frequently very heavy. Good results in prevention have been obtained, both from steaming and from formalin drench as per directions in seed and soil treatments. The fungus also attacks the succeeding crops of tomatoes, cucumbers, etc. Attention must in all cases first be given to growing healthy seedling plants, to be followed by soil disinfection. See Circular No. 57).

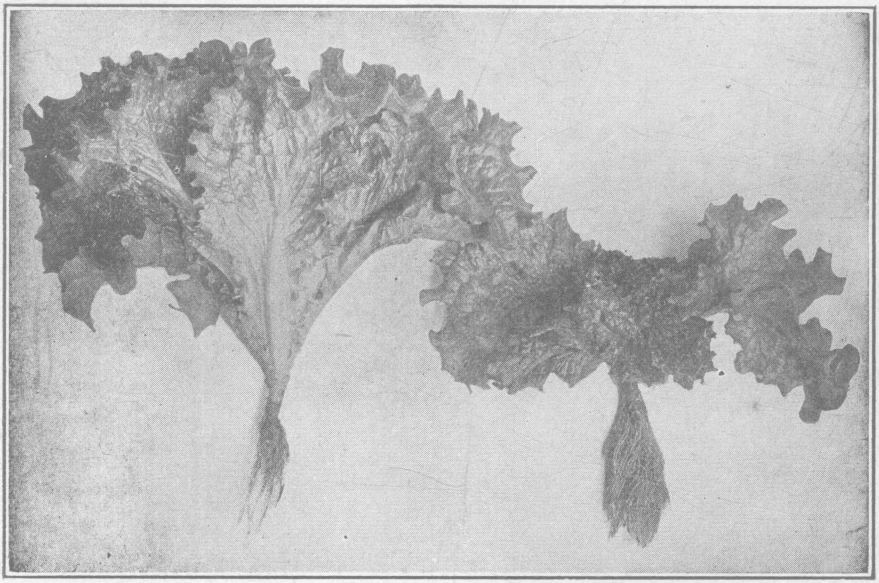


Fig. 56. On the left is shown a healthy lettuce plant, on the right diseased lettuce plant with Rosette effects produced by inoculation of pure culture of Rhizoctonia. The effect of the Rosette Fungus is shown in destroying absorbent rootlets and in the growth of additional new roots; it also prevents the proper development and elongation of the axis or stem of the plant. From Circular No. 57. (See also Fig. 57).

Lettuce Rot or Lettuce Drop. This is by all odds the most troublesome disease to the lettuce grower. The plants may rot off at the surface of the earth and the central parts, especially of head lettuce, may become attacked by the rot fungus (*Sclerotinia* ***Libertiana*** **Fckl.) (*Botrytis vulgaris* Fr.).** The fungus appears as a whitened covering with a liberal production of spores in clusters. At this Station it has not been possible to succeed with the head lettuce because of the rot. Fumigation of house, the use of fresh or steamed earth each year and the careful regulation of temperature and water supply, seem to be the measures most favorable to prevention. A low night temperature, less than 50 degrees F. is very desirable, while too high a temperature will usually result in disease. Ventilation is all essential during the day. It is desirable also to gather and burn rotted leaves and plants.

Leaf-Spot. The leaf-spot fungus (*Septoria consimilis* E. & M.) is frequent upon wild lettuce plants and occassionally upon outdoor lettuce, especially in late seasons. The small characteristic leaf-spots are not difficult to distinguish from anthracnose. The remedies are confined to avoidance.

Root-Rot and Stem-Rot. A bacterial stem-blight has been described from Vermont, but has not been found with us. A recent stem-rot infection closely resembles rosette in the behavior and form of affected plants. Microscopic

examination shows that the stem tissues are somewhat brown and that the brown and dead rootlets are occupied by the fungus which is referred to a species of Fusarium. This disease is at present under investigation and should be controlled, if at all, by the thorough soil treatments recommended under lettuce rosette. It will be no use to disinfect the houses and then grow plants in diseased soil.

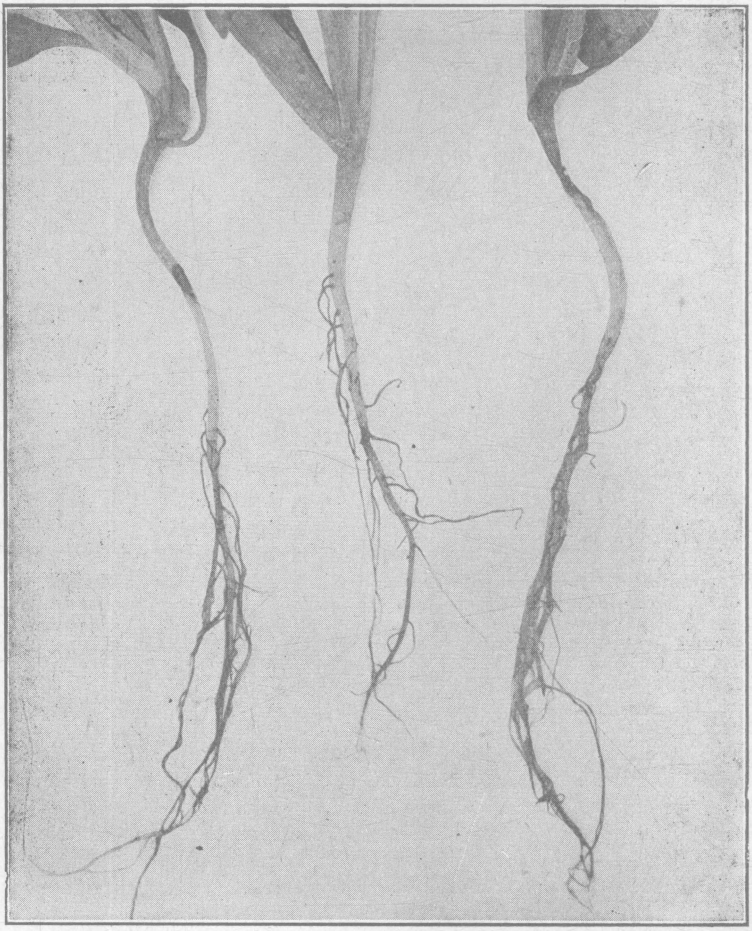


Fig. 57. This shows root portions of seedling lettuce plants with dark spots, lesions caused by attacks of the rosette fungus, *Rhizoctonia*. With the younger plants these attacks cause large mortality and in very small seedlings the stem of plantlet may early collapse after the manner shown in rotting specimens. (From Circular No. 57).

Tip-burn. Tip-burn of lettuce leaves is often brought to notice. Usually it is associated with unsatisfactory watering in the greenhouse, or with extreme changes to summer weather. The remedy consists in the methods of watering employed.

LILY

Lily diseases are frequent in all lily growing districts. With us no study has been made, as little complaint is made to us. Doubtless the chief factor is to secure healthy bulbs.

LOCUST

Heart-Rot (*Trametes robiniophila* Murr. and *Fomes rimosus* Berk.). In southern Ohio the locust is reported as suffering from a heart rot trouble, but to which of the several species occurring in different parts of the United States, we must ascribe most injury we are not yet able to decide. Both species occur in Ohio. The rot is described as infecting the heart of much of the trunk, so that trunks may be of no value above the first post length or less from base. The heart wood is converted into punk and the fungus fruits externally, as is commonly the case.

LUPINUS

Several species of lupinus are used for ornamental or other plantings and are liable to the same group of diseases as are found upon alfalfa, clovers and pea.

MANGEL-WURZEL

Mangel-wurzel being a near relative of the beet is liable to be attacked by essentially the same diseases as the garden beet. These are usually leaf-spot, rust, dry-rot, etc.

MAPLE

Anthracnose. (*Gloeosporium apocryptum* E. & E.) This disease attacks young Norway maples (See N. Y. Sta. Report '95) and has been also identified on the young shoots of sugar maples in Ohio. The new leaves were reported destroyed by the fungus which is much more common in Ohio on sycamore trees. Applications of Bordeaux mixture should check this disease.

Rhytisma and Leaf-spot. The leaves of cultivated maples are often disfigured by dark colored incrustations following the line of the veins. These incrustations are almost black and are caused by a fungus, (*Rhytisma acerinum* (Pers.) Fr.) The trouble is usually not serious, but if prevalent it would seem advisable to gather and burn all leaves attacked by it. The leaf-spot fungus (*Phyllosticta acericola* (Cke. & Ell.) often causes small spots, or dead areas, in the leaves. This may sometimes prove so serious as to call for applications of fungicides.

Mildew. Maple leaves are overrun by the powdery mildew fungus (*Uncinula*) at times, but this is not difficult to check even if spraying becomes necessary.

Tip-Burn—Sun-Scald. Tip-burn conditions upon the maple in 1908 and 1909 were similar to those described for horse chestnut and evidently due to secondary consequences of insect punctures.

Sun-Scald or winter injury effects are frequent upon maples after the manner of those described for apples. They are due to a killing of unripened tissues by premature freezing and are only preventable by avoidance.

MILLET

Leaf-Spot. Leaves of millet, dying from small, light-colored spots, were recently examined. These spots are due to a fungus (*Piricularia grisea* (Cke.) Sacc.) and the dying may at times be enough to shorten the yield of forage.

Smut. The seeds of millet are often attacked by the millet smut fungus (*Ustilago Crameri* Kornicke) which transforms them into black masses of smut spores, much after the manner of stinking smut in wheat. This is liable to injure the feeding value of the millet, although it is not likely that the smut will injure stock when millet is fed in the usual quantities. All smutted grain, of course, is ineffective and useless, and the smutted seed when again sown will produce a smutted crop. The smut is prevented by the same hot water seed treatment as that applied to prevent oat smut. In experiments conducted by the Botanist of this Station this treatment was successful.

MULBERRY

Bacterial Diseases. Russian varieties of mulberries have new growths, especially new sprouts attacked by a bacterium. These deep dark lesions result in cankers and all the various phenomena of the plant's effort to heal a wound in the wood. The trouble is so difficult to handle that where Russian mulberries are badly attacked, rejections may be necessary.

Leaf-Spot. Mulberries are at times attacked by a leaf-spot (*Cercospora moricola* Cke.) but this is rarely serious in our district.

MUSKMELON

Anthracnose. The common anthracnose fungus of the muskmelon (*Colletotrichum Lagenarium* Pass.) is the same as that of the cucumber. It attacks the stems of plants of all sizes as well as the leaves, resulting in the lesions of the stem and dead spots in the leaves. In these the fungus produces the fruiting bodies. After the seedling stage is passed it is usually possible to keep the anthracnose in check by the spraying as recommended for cucumbers.

The fruit anthracnose of the muskmelon (*Colletotrichum oligochaetum* Cav.) is widely distributed and has occured with us. It forms yellowish, diseased spots on the fruits and may disfigure them considerable. It is too soon with us to estimate possible losses from it. Thorough spraying with Bordeaux mixture should hold it in check if begun on the young fruits and repeated once or twice at intervals.

Black-Spot. In 1908 a case of black-rot or spot-rot of muskmelon fruits was reported with specimens. The spots were depressed and accompanied by decay. No definite causal organism was determined, although one or more were present in the spots. It is believed that spraying will hold it in check but the case was referred to us to late to test this.

Downy Mildew of muskmelon is caused by the same Plasmopara fungus as the downy mildew of cucumbers. As we have the fungus in Ohio it does not appear until towards the middle of August, but is then very destructive, sweeping rapidly over the melon fields and leaving only devastation behind. In its attacks the spots of the muskmelon leaves are somewhat different in shape and usually of a darker color than in the case of the cucumber. One with experience can readily distinguish by the use of an ordinary hand-glass. He will then see on the under side of the leaf the violet spores and spore-bearing

threads of the mildew fungus. The melons which are unripened upon the vines when attacked by mildew are practically worthless and for this reason large losses are usually incurred. The treatment is by Bordeaux mixture, as for cucumbers.

Muskmelon Leaf Blight is a disease more or less peculiar to the muskmelon, although the fungus (*Alternaria sp.*) which causes it has also been found upon cucumber leaves. The leaf blight causes rather large dead areas in the leaves which are usually distinguished from those of downy mildew by their larger size and the tendency of the central portion to break out. The prevention of muskmelon leaf blight is by no means an easy matter, requiring of itself great thoroughness and carefulness in the application of the Bordeaux mixture and also requiring that the downy mildew shall be watched during the same period. For this reason earlier sprayings, if made before August 1st, should be repeated at fortnightly intervals, while those after August 1st should be at weekly or ten-day intervals. Melon growers have succeeded by following these lines, while others who were less thorough were less successful, or failed entirely. The treatment is recommended with confidence. (Bulletins 73 and 105).

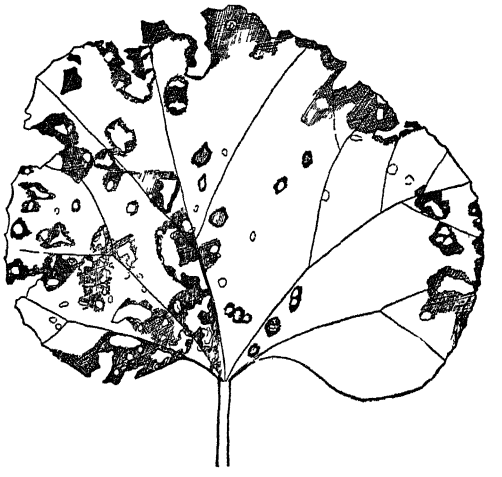


Fig. 58. Muskmelon leaf attacked by leaf blight. The dead spots are caused by a species of Alternaria. From Bulletin 73.

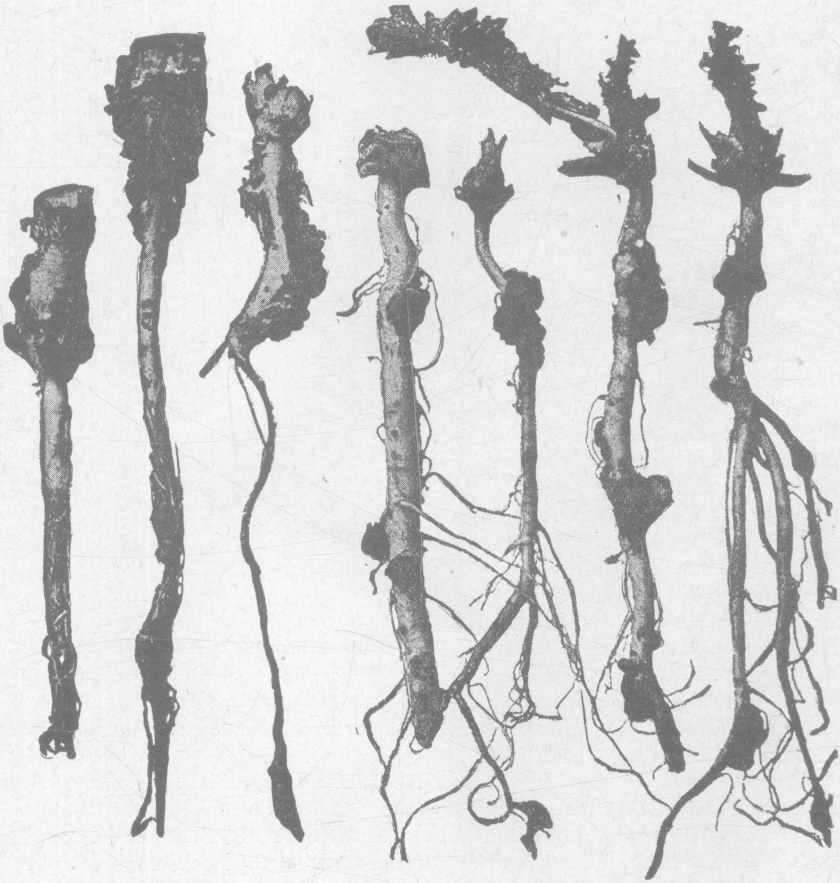
Root-Rot. (*Rhizoctonia*) The root diseases accompanied by rotting of the rootlets and induced by the sterile fungus of lettuce rosette is also found on greenhouse muskmelons. This is liable to be the case where these follow diseased crops of lettuce. The prevention is the same as that for the cucumbers, viz., thorough soil treatment.

Muskmelon Wilts are the same in general character as those described for the cucumber. Not only the bacterial wilt disease but the wilt due to fusarium has developed upon muskmelons in this state. The symptoms are the same as for cucumbers, namely: sudden wilting as from lack of water, followed by dying. The prevention treatment is the same as before recommended.

MUSTARDS

Black-Rot. Mustard plants of all species are liable to be attacked by black-rot and if permitted to grow as weeds in fields devoted to cabbage growing and will carry the black-rot trouble through the rotations in spite of the grower's other efforts. Let no mustard weeds survive in such rotations.

Club-Root. Mustard plants generally are attacked by the club-root fungus (*Plasmodiophora Brassicae* Wor.) when this is present in the soil. For this reason the weeds of several species may be infested upon lands that have never been brought under cultivation. Due attention should be given to mustard plants in new lands when designed for cabbage.



Figs. 59-60. Figure 59 on the left shows roots of shepherd's purse. Figure 60 on the right, roots of hedge mustard. Both are attacked by club-root. Both after Halsted. Bulletin 98, N. J. Exp. Sta.

Downy Mildew. The downy mildew fungus of crucifers (*Peronospora parasitica* (Pers. (De By) is so universal on plants of the mustard family that it may be usually expected. The weedy species may accordingly keep up the supply of the parasite which attacks cabbage and cauliflower as well as others of the family.

Wilt. It is very necessary that search be made as to the survival of the fusarium of cabbage wilt on mustard weeds.

OAK

Anthracnose. The oak leaves are attacked by the same anthracnose fungus as attacks the leaves in young shoots of sycamore and maple, but this is not so prevalent upon oaks in Ohio as upon the sycamore.

TIMBER ROTS

Wound or Timber Rots of oaks are as yet imperfectly studied and call for thorough investigation before many statements can be made for us.

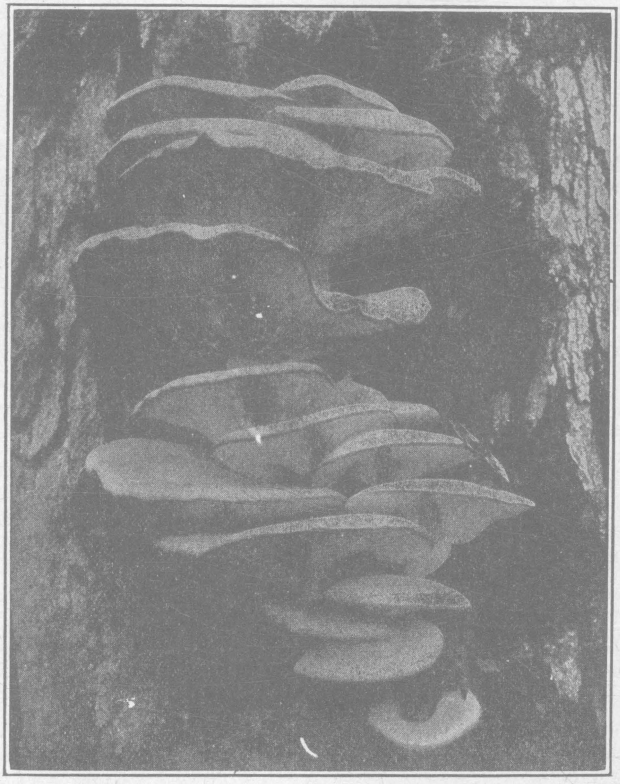


Fig. 61. A wound parasite (*Pleurotus ulmarius*) on the trunk of a maple tree. (After Freeman, Minnesota Plant Diseases).

OATS

Anthracnose (*Colletotrichum cereale* Manns.) is a new disease of oats which attacks the roots and basal portions of the culms together with the lower sheaths. The attack may extend even further than has yet been determined. The spores of this fungus were found adhering to seed oats of the crop of 1907 and the outbreak of the disease was studied in 1908. It shows by the development of the characteristic dark masses or acervulæ of the anthracnose fungus upon the lower joints of the stem, portions of the root and leaf sheaths.

The amount of loss resulting from it is liable to be variable since it acts by general reduction of vigor and reduced filling of the grain head. Treatment with formalin as for smut will certainly kill the adhering spores on seed oats. (See bulletin 203).

Blade Blight. A disease similar to that earlier described as bacterial disease of oats (see Journal of Mycology, VI; 72) has been very serious in Ohio during the seasons of 1907 and 1908. The phenomena are those of yellowing and dying of older leaves associated in most cases with the presence of an abundance of leaf sucking insects such as aphids, mites and leaf hoppers. Recent culture and colonizing studies made at the Station show the disease to be due to two specific bacteria working together. (*Bacillus avenæ* Manns.) (*Pseudomonas avenæ* Manns). These have been isolated and described. These bacteria are carried or transmitted by the insects or are scattered by natural agencies. In control work in cages the organisms caused infection through the punctures of the aphids (green flies). Evidently the control of this disease will involve thorough seed treatment together with possible field checking of the insects distributed. (See bulletin 210).

Rust. In addition to the two species of rust found upon wheat and to be given under that grain, there is a rust common upon oats (*Puccinia coronata* Corda.), usually prevalent during the rainy harvest weather and more or less at all times. No remedy is as yet at hand.

The Scab Fungus of the oats (*Fusarium roseum* Lk.) is the same species as for wheat and attacks the panicles near filling time. It results in empty hulls with the pink fungus. The disease also survives apparently as an internal infection of oat kernels and is capable of destroying young seedlings after the manner described for wheat. (See diseases transmitted in the seed and also wheat). Like that disease in wheat, it must be controlled, if at all, by a combination of seed treatment for adhering spores and thorough seed recleaning to exclude all light kernels.

Smut. The smut of oats takes on two forms, the loose smut (*Ustilago Avenae* Jens.) and the hidden smut (*Ustilago Avenae laevis* (Jens.) Kell. & Swing). The first, which is the more common, converts the entire head, including glumes, into a sooty mass of smut spores (Fig. 62); while in the hidden smut the enclosing glumes remain about the smutted grain. No other essential difference has been found between them. Both are caused by spores from smutted seed, or seed from smutted grain, and both are successfully prevented by seed treatment with hot water or formalin as per scheme given elsew here. (See calendar and also Bulletins 64 and 97). An increase of yield beyond smut prevention has usually followed seed treatment. This alone pays for the cost of treatment and the saving from smut loss is clear profit.

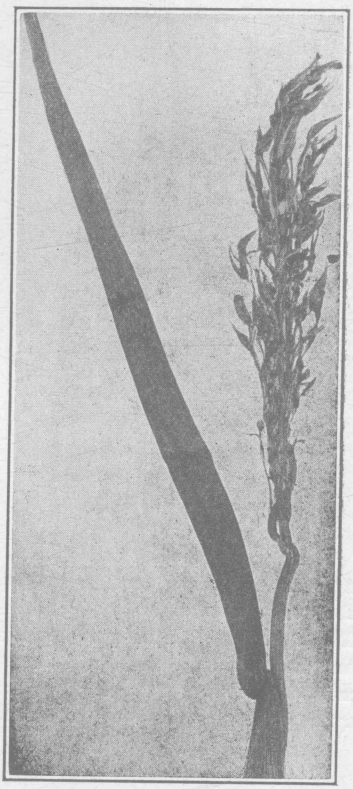


Fig. 62. Head or panicle of oats destroyed by loose smut. All the oats kernels and many of their surrounding parts have been converted into black, soot (smutty) masses by the loose smut fungus *Ustilago.*

OAT-GRASS

Anthracnose. The same anthracnose fungus (*Colletotrichum cereale* Manns.) before described as attacking blue-grass, chess, oats, wheat, rye, etc., also occurs upon oat-grass. It is less liable to cause serious injury here than on the cereal grains.

Smut. There has been at the Station a smut on tall oat-grass (*Arrhenatherum elatius* L.) which closely resembles loose smut of oats but is, in fact, a separate species of smut whose mycelium survives in the rootstocks of the oat-grass (*Ustilago perennans* Rostrup.). The smut is thus continued in the same plants from year to year. It is not clear whether the smut would be transmitted in new seed, but there is some danger, at least.

ONION

Bacterial Disease. See heart-rot below.

Blight. Leaf blight or scald of onions during mid-season, when the weather is warm and dry, is rather a common occurrence. This was especially noticeable during 1898 and 1899. While often attributable to insects, species of fungi, especially molds (*Macrosporium Sarcinula parasiticum* (B.) Thüm—*M. Porri* Ell.) were abundant in the seasons named. It may be possible to check these molds by spraying.

Fusarium Blight. This is often serious on young onions in old soil and is the forerunner of heavy losses from soft rot in storage.

Downy Mildew (*Peronospora Schleideniana* D'By.) is likely to occur upon onions, although it has not been seen in Ohio by the writer. The treatment would be as for downy mildew of other plants.

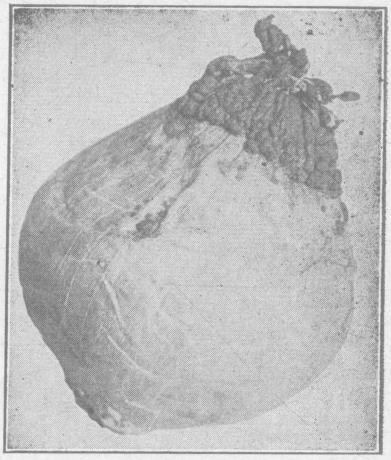


Fig. 63. A white onion that has been destroyed by a blackneck or dry-rot fungus, *Sclerotium cepivorum* Berk. This parasite has entered the onion through the green neck which was cut off at the time of harvesting the crop, (From a photograph by T. F. Manns).

Dry or Black Neck-Rot is the most serious disease of white onions in Ohio since the losses are so very large from it, particularly in Hardin County. The white onions are grown for somewhat special markets and it is the custom, at present, to gather early before the tops fall over, to top at once, and put up in crates in order. to preserve the white color of the onion. As a rule this is not practiced with black, red and yellow sorts, so that this neck or dry-rot is not so common with them. Preliminary investigations have been made of this trouble and it appears to be clearly different from the smudge fungus which also disfigures the exterior of white onions. The fungus of dry-rot or black-neck (*Sclerotium cepivorum* Berk.) requires further investigation. (See Sorauer Pflanzenkrankheiten third edition, II 302-3). In Ohio onion districts the losses are very serious between the gathering of the white onions and time for winter storage while the crates are piled in buildings or in covered ricks in fields.

It appears at this time that the early topping of the white onions, leaving a green neck, offers an inviting way for the disease to enter; that the invasion is in this direction appears from the sclerotia of the fungus which forms in this region. (See illustrations). The disease appears to grow worse with continuous cropping of onions and the losses have recently been so large in storage as to render storage of white onions unprofitable. It has been suggested by this department that the white onions should be gathered and ricked in crates at once, either in buildings or covered with tent or temporary enclosure of building paper and disinfected or treated with formaldehyde gas as per the spray calendar. (See formula elsewhere). The enclosure should not be opened for 24 to 48 hours after treatment. In this manner it is hoped to keep down the infection of the white onions as well as of any others from similar troubles.

Heart-Rot. (Bacterial). This disease has been under investigation and appears to come in all varieties of onions, following the topping, by its rapid invasion of the center of the bulb through bacterial infection. It should be controlled by attention to disinfection of the topping machine or to similar treatment to that recommended for dry-rot. This disease ends in the complete destruction of the bulbs through a soft rot diferent from that described under soft-rot.

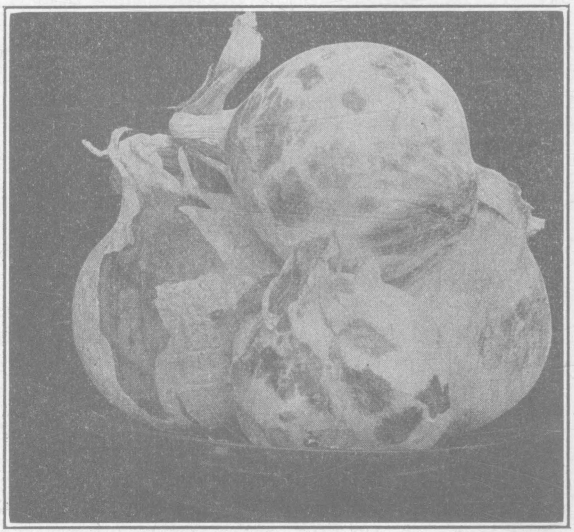


Fig. 64. Onion spotted by the smudge fungus. This fungus becomes very bad in land where successive crops of onions are grown. The fungus is also a factor in causing dry-rot of onions and set onions.

Smudge. This fungus (*Vermicularia circinans* Berk.) develops as a superficial spotting upon the exterior, especially attacking the white varieties; it is really an anthracnose of onions. For some time, because of its coincident development with the black neck or dry-rot, these two troubles have been confused. It is now apparently clear that there is no connection between the two, although this fungus causes dry rotting of sets and bulbs. The smudge fungus is cumulatively worse on old land where onions are grown consecutively. Apparently also in addition to rotation of crops the formalin drip treatment described under smut gives good results in keeping down this fungus. In field experiments made heretofore, the onions have been lost in storage from the dry-rot and the smudge disease has not been studied very fully in storage; apart from this it is believed to have little or no connection with the commoner storage rots, although the disfiguring effects of badly spotted onions reduce their market value, and rotting does take place as a result of it. The illustrations give characteristic appearances of these compared with healthy onions.

Onion Smut, on the other hand, is prevalent to a considerable extent in Ohio, and is one of the most destructive of the smut fungi known to pathologists. This onion smut (*Urocystis Cepulae* Frost) unlike the other smuts with which we have to do, propagates itself almost indefinitely in the soil when this once becomes infested. Whenever a new crop of onions is grown from seed in this infested soil the smut attacks the young seedling onions, in whole or in part, and a very considerable loss results therefrom. If, however, onions sets are put in such soil, or seedling onions that have been started under glass in healthy soil are transplanted to smut infected soil, the smut fungus cannot attack them. The explanation seems to be that the smut threads are only able to penetrate the leaves of the young, tender seedlings. This onion smut is now known to occur in fields at Berea Perry, Madison and near Chillicothe. At the latter place it has seriously embarrassed some of the growers of onions for sets; for this work transplanting is, of course, out of the question. In Connecticut Experiment Station Report for 1889, it is stated that flowers of sulfur have been used to sow with the seed in infested soil, and this remedy has given but slightly inferior results to any other yet tried at this Station. Forty percent formalhyde, known commercially also as formalin, has given better results than sulfur in 1900.

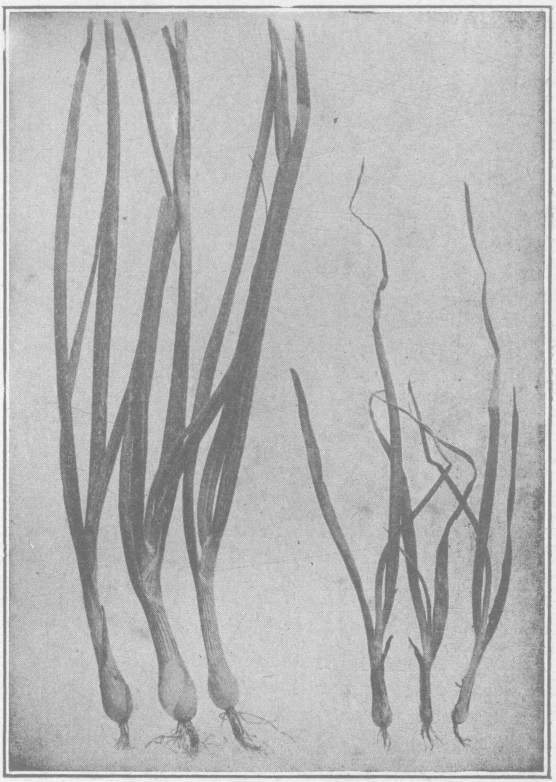


Fig. 65. Sound and smutted onions, gathered in midsummer The healthy onions were grown on badly diseased soil by the use of Formalin Drip treatment.—From a photograph by T. F. Manns.

At Berea, Chillicothe and latterly at Madison, experiments have been conducted to determine a practicable field method for smut prevention. The best method has proved to be that of formaldehyde drip with seeder. (See bulletin 131). The formaldehyde solution is made at the rate of one pound of 40% formaldehyde to 25 to 33 gallons of water. This is applied with drip attachment on seed drill at rate of 125 to 150 gallons per acre for field onions. The same results can be obtained in open furrows by applying solution with sprinkler after seeds are scattered until well moistened. This formalin treatment insures the disinfection of a layer of soil near the seed and permits the germination and the early growth, of the seedling onion, past infection stage, before the smut fungus can again occupy this soil. The gains from this treatment, both in the onion set work and in field onions are very large, amount-

ing to 100% to 200% increase. This method has recently been applied successfully in the Connecticut Valley by a representative of the United States Department of Agriculture.

Soft-Rot and Storage Rots. The Assistant Botanist has recently studied a soft-rot (*Fusarium* sp.) of onions which shows in field, but more seriously in subsequent storage. This soft-rot is produced by the fungus Fusarium, yet under study. It not only causes an early blight but also invades the onion bulbs quite rapidly after storage infection. The problems of control are essentially those of storage rots including dry-rot.

In onion storage it seems to the writer probable that disinfection of the onions after placing in storage buildings either by sections or otherwise: using the formaldehyde gas treatment will give excellent and safe results. This needs yet to be worked out.

ORANGE

In greenhouses oranges are frequently grown and complaints come to us as to the troubles upon them. The chief of these troubles is a black mold (*Capnodium citri* Berk. & Desm.) on the foliage and at times upon the fruit. Spraying with fungicides has usually brought satisfactory results and develops no special injury to orange foliage.

Fruit Rots. Orange rots in stored fruits are often brought to our attention, but do not properly belong to our state work. They are the result of mold attacks following bruising. The blue mold fungus (*Penicillium glaucum* Link.) and the green mold fungus (*Penicillium digitatum* (Fr.) Sacc) are both common. These are described in other publications. (See Bul. 8, Bureau of Vegetable Pathology, United States Department of Agriculture, also Bul. 184; Calif. Exp. Sta.).

ORCHARD-GRASS

Anthracnose. Orchard-grass is attacked by the same anthracnose (*Colletotrichum cereale* Manns.) as attacks wheat, rye, oats, blue-grass and timothy. The development is shown in a similar way by the black masses of the fungus upon the basal portions of the culms and sheaths.

PALM

Leaf Diseases. Frequent complaint is made of palm leaf diseases in conservatories; the department has been able to study these but little and finds more often that they are the result of over-watering. Several diseases have been reported on palm leaves. Among these we have an anthracnose fungus (*Gloeosporium Allescheri* Bres.) of Kentia. Dr. Trelease has reported upon another fungus on Phoenix (*Exosporium palmivorum* Sacc.). This also attacks the leaves causing ultimate death. Another leaf disease is described from Europe upon Chamaerops (*Graphiola Phoenicis* (Mong.) Poit.). It is caused by a fungus which is not infrequent on the date palm. Sprays such as Bordeaux or Lysol are recommended for these palm leaf diesases.

PEA

Anthracnose. The anthracnose or pod-spot of the pea (*Ascochyta Pisi* Lib.) often develops into a serious blight of field peas grown for canneries. This was studied by the department and it was found that the anthracnose fungus infects the seed peas so that these when planted give diseased seedlings and the consequent loss of crop. (See Bul. 173). The illustrations will show how the fungus spots the pods and thus has an opportunity to enter the developing

seed peas. It was shown by spraying experiments with Bordeaux mixture that healthy seed peas may be grown. The growth of healthy peas for seeding disposes of the problem of anthracnose.

Leaf-Spot. Other leaf-spots besides those of the anthracnose are sometimes found upon the pea and are apparently caused by another fungus (*Septoria Pisi* West.) These, if giving trouble, will be controlled by the spraying for anthracnose.

Powdery Mildew (*Erysiphe communis* Wallr.) The mildew fungus often attacks the pea and at times entirely destroys its fruitfulness. It may be known by the whitish coating produced upon the leaves and by the dark, pin-head spots of the fungus observed to be situated in these white coverings. The same fungus likewise attacks the bean. For either plant spraying with Bordeaux mixture, as per directions in calendar, will be found beneficial. The first applications should be made promptly.

Wilt. A wilt of pea, apparently allied to that of cow pea ond other forage crops of the south has been referred to a species of fungus *Neocosmospora* (*Fusarium*). As yet it has not been especially studied in Ohio.

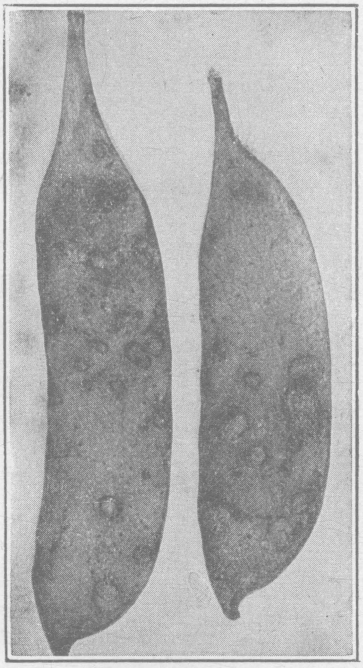


Fig. 66. Pods of French June field pea spotted by anthracnose. After Van Hook, Bulletin 173.

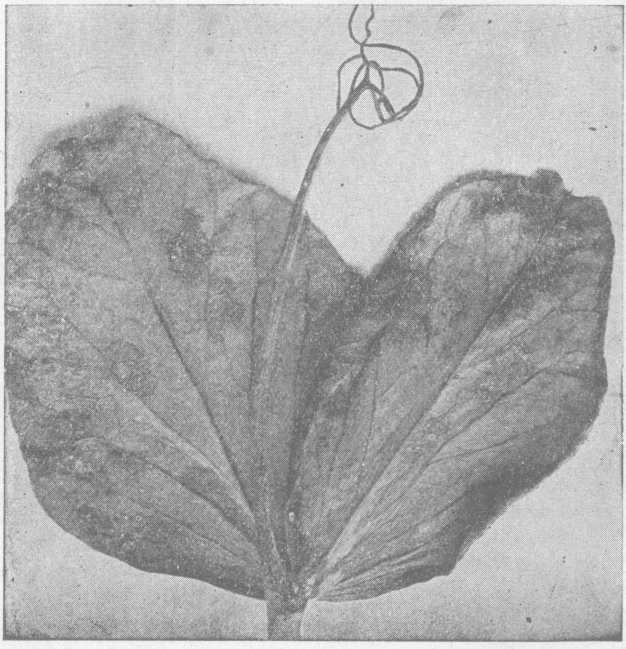


Fig. 67. Leaves of pea showing spots caused by anthracnose fungus-slightly magnified. After Van Hook. Bulletin 173.

PEACH

Anthracnose. An anthracnose fungus (*Gloeosporium laeticolor* Berk.) has been described upon the fruit of peach and has been found in Ohio, though rarely. Careful spray treatment as for scab should be successful against this disease.

Crown Gall. This is a very contagious disease of the peach and of other plants, notably daisy, raspberry, and blackberry, due to a bacterium (*Bacterium tumefaciens*) Sometimes it produces excrescences and enlargements upon the root and branches of the affected plant. More commonly the galls are found upon the stems just below the surface of the earth. These vary in size and in location, even occurring upon the small roots, and less frequently upon the stem at some distance above the ground. In some recent experiments (Bulletin 104) it was found that the gall trouble became communicated from diseased raspberries to peach trees set in the plantation. In some instances the loss from crown gall has been large and there is, in my judgement, no other disease common to several of our fruit trees that is so threatening in its ravages. The peach trees attacked in most cases perish without producing fruit. This applies when the trees are affected at nursery age—the usual condition. Purchasers cannot afford to set such diseased trees nor nurserymen to ship them. As yet the only treatment that we can recommend is to dig out and burn the diseased trees, and to avoid planting affected stock. Indeed no affected stock should be received. This, with other diseases, has been treated in Bulletins 92 and 104.

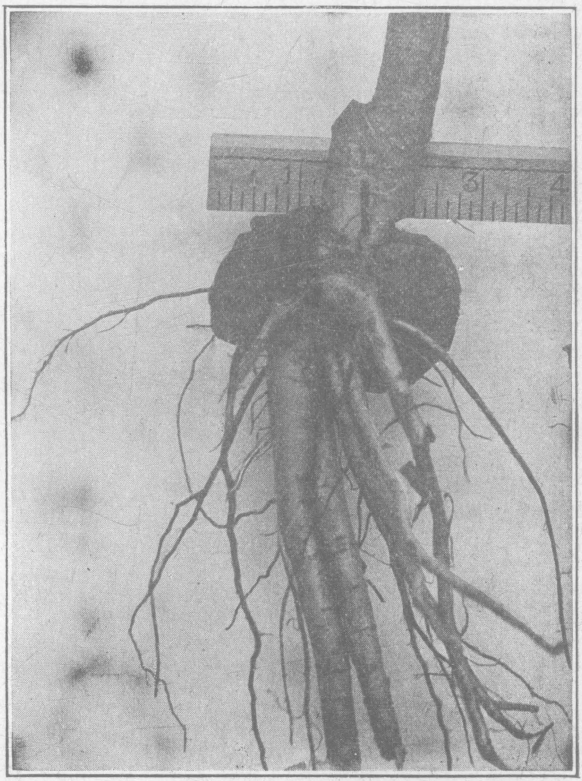


Fig. 68. Root of nursery peach tree attacked by crown gall.

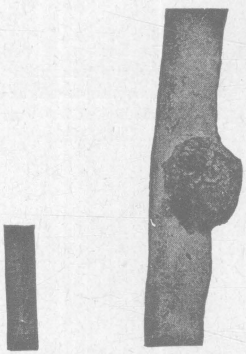


Fig. 69. Crown gall attacking stem of peach tree.

Frosty Mildew. Occassionally the frosty mildew fungus (*Cercosporella persice* Sacc.) occurs, whitening over the under surface of the leaves. As yet it has not been a serious disease.

Gum-Flow. The gum-flow diseases of the peach are frequent but have, as yet, been imperfectly studied in our state. We have no distinct gummosis, although in some varieties of peaches it would seem this is a weakness or a form of injury due to climate followed by gum exudations. Bark borer injuries produce a well-marked gum-flow.

June Drop is often named by peach growers as a specific trouble. It consists in the dropping of the young peaches during the month of June, though dropping sometimes comes earlier. The cause seems to be physiological and need not be feared where the trees have been prevented from overbearing, or protected from the effects of drought by thorough cultivation the previous season.

Little Peach is a disease much discussed in Michigan and is quite serious in the fact that the peaches on diseased trees never come to proper maturity or develop marketable character. Dr. Smith has found that the root hairs on many such trees are not healthy and thus it appears that some specific trouble is located there.

Leaf-Curl (*Exoascus deformans* B.). The leaf-curl fungus is at times one of the serious pests of the peach grower. However, destructive leaf-curl does not occur every year. The curl fungus survives as mycelium in the buds from year to year. It is therefore present each season, though possibly in varying amount.

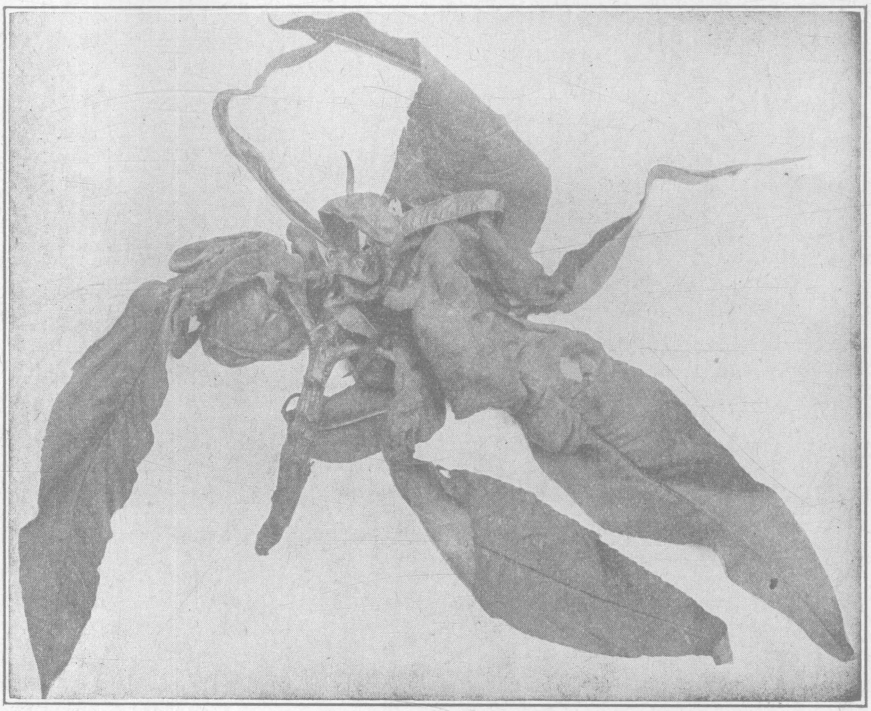


Fig. 70. Leaves of peach attacked by leaf-curl. The attack of the fungus causes rapid cell multiplication and results in the distorted shapes. From a photograph.

Fig. 71. Eleven-year-old Elberta peach tree, unsprayed, defoliated by leaf-curl. No fruit. From Bulletin 148.

Fig. 72. Eleven-year-old Elberta peach tree, sprayed, March and April, 1903, with soda-lime-sulfur-vitriol, under direction of the owner. Foliage and fruit crop saved by the treatment. From Bulletin 148.

We have found in Ohio that serious leaf-curl comes when cool weather, with frequent rains, prevails during April, May and June. It is to the April weather that the most serious trouble seems attributable. With low temperatures and frequent rains during the early half of this month we may safely predict an outbreak of leaf-curl (Bulletin 92). During such weather the fungus develops rapidly and the new leaves are affected as they are protruded from the bud. In a modified sense the same takes place during May and in a still more limited sense during June. Successful prevention of leaf-curl is secured by thorough early treatment with Bordeax mixture. Indeed, it appears that a spraying at any time shortly before the blossoms open is several times more effective than any application afterwards. It appears that more effective results are secured by spraying two weeks before blossoming than immediately before the blossoms open. In any event an application made just before the blossoms open is more effective than at any later date. Lime-sulfur applications for scale insects are effective to prevent leaf-curl. Whale-oil soap has also proved effective applied at this time, though not safe at much earlier dates. It is more expensive than Bordeaux mixture. (See Bulletins 104 and 148).

Leaf-Spot of the peach may be due to a variety of causes and in no cases studied have they proved destructive. One fungus (*Cercosperella persicæ* Sacc.) is often mentioned. These leaf-spot are illustrated and very briefly discussed in Bulletin 92.

Pustular Spot of the peach is a disease referable to a minute fungus (*Helminthosporium carpophilum* Lev.) which is apparently spread by spores that alight upon the upper surface of the fruit, flourish there and produce minute, light-brown spots, often surrounded by an angry red border. The red border is conspicuous in earlier varieties and is sometimes elevated and pustular in appearance. This fungus greatly disfigures the fruit and is very easily prevented. Three applications of Bordeaux mixture have reduced the amount of pustular spot to less than one percent; whereas unsprayed trees gave more than sixteen percent of spotted fruit, much of which was seriously damaged. (Bulletin 92).

Powdery Mildew (*Sphaerotheca pannosa* (Wallr.) Lev.) sometimes attacks peach in our state, but rarely with serious results. The attacked leaves sometimes turn white and are sometimes distorted. Spraying with potassium sulfid or self-boiled lime-sulfur would be successful.

Rot or Brown-Rot. The brown-rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.) Schroet) is among the most destructive of the fungi on the peach, yielding place only at times to leaf-curl. Unlike leaf-curl the brown-rot prevails during warm, showery weather, and with such a weather period is likely to occur at any time of the year. In April, if the mummy peaches are permitted to remain on the trees from the preceding year, the fungus may affect the twigs through the blossoms and thus cause serious twig blight. It is a matter of common remark that the branches upon which rotted peaches are found often perish from the effects of the rot fungus. The survival of the fungus in these "mummy" fruits and the production of ascospores from them are well proven. No one variety seems more susceptible to rot than others, although some sorts are more liable to ripen during rainy weather and then rot worse. The

Fig. 73. Rotted and dried or mummy peaches collected on trees in spring. These mummies will produce growth of the rot fungus with showery, warm weather. They are dangerous.

control of rot demands: First, careful removal and destruction of all mummy rotted peaches in which the fungus survives; Second, thorough spraying of the trees before blossoming, as for leaf-curl; Third, subsequent spray treatment with self-boiled lime-sulfur as per calendar, may be profitable under certain conditions.

Root-Rot. In some instances, notably at Gypsum, Ohio, where peach trees were planted in a dense, clay soil, the roots often decay, apparently from the attacks of some fungus. Trees thus attacked usually perish soon. Whether the trouble is primarily due to the fungus or to the location in which the trees are grown has not been determined.

Fig. 74. Peaches of the Salway variety with one side blackened and cracked from scab. This loss is prevented by proper spraying.—From Bulletin 148.

Another root-rot has been further studied and found to be prevalent where orchards are set in newly cleared land, if following growths of oaks. The attack upon the roots show the rhizomorphs of the root-rot fungus as in apple root-rot which has later been more often noted in the west.

Rust. A rust fungus occurs upon the peach but not to a serious extent in Ohio.

Scab or Black-Spot. This fungus (*Cladosporium carpophilum* Thum.) is a serious drawback in the growth of certain varieties which seem susceptible. These are Morris, White, Salway and some other late sorts. It causes dark spots upon the fruit followed by cracking and entrance of the rot fungus with serious results. To control this disease, spraying results reported in bulletins 104 and 148 obtained by the use of dilute Bordeaux mixture were very satisfactory, but secured with some injury to peach foliage. In 1908-9 studies were made in an orchard near Brownhelm where self-boiled lime-sulfur was tested in comparison with dilute Bordeaux mixture. The results are very promising and indicate that self-boiled lime-sulfur is the remedy to be applied at intervals of two to three weeks after foliage appears.

Stem Blight. A stem blight of the peach was studied several years ago by the writer. (See bulletin 92). It is due to a specific fungus which in this instance attacked the stems of nursery stock causing a constriction, and this is

in line with the effects of the fungus described from Europe as a constriction or lacing disease. While in the case studied there was loss of nursery stock, due possibly to some injury to which it was exposed, there has been little recent trouble. Infection may surely be prevented by treatment with fungicides.

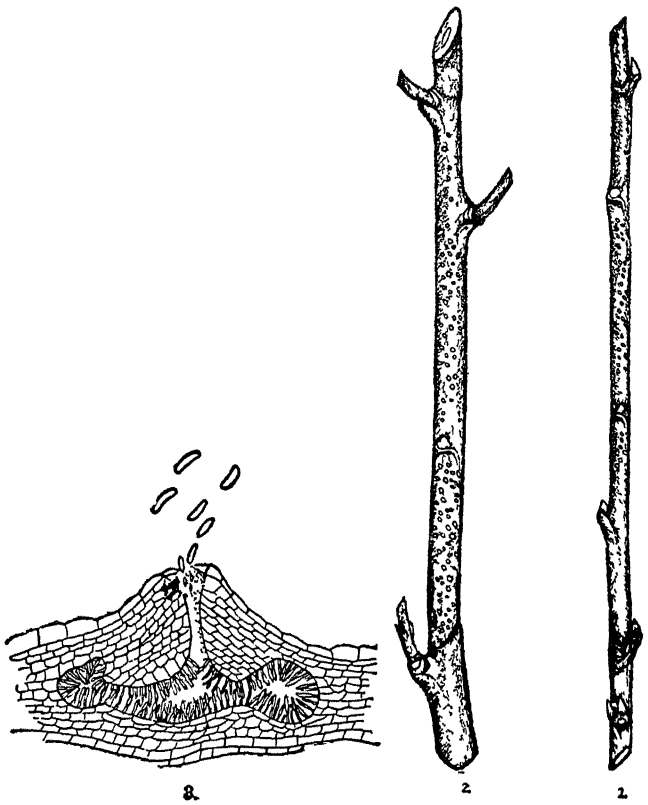


Fig. 75. Stems of nursery peach trees attacked by Constriction fungus. (*Phoma persicae* Sacc.). The trouble causes dying out of the diseased parts of the stems which are shrunken where attacked. The detail structure of spores and pycnidia are shown magnified about 500 diameters.—From Bulletin 92.

Winter Injury. In our climate the severe freezing of winter often injures the trunk and branches of peach trees. The common killing back of new growth by freezing is a familiar phenomenon. The common killing of the trunk on one side, usually the west or southwest, is also known. Many instances have been studied. Wherever there has been late growth of the trees, followed by severe winter cold, such injury may be expected. Late cultivation is therefore to be avoided. Winter injury to fruit trees may be attributed to the drying out of the trees and it is worth while to consider whether by mulching, or soil conditions, the tree may not be made to have an abundant supply of available moisture, when the upper soil is frozen hard. Much injury to peach trees from freezing occurred during February, 1899, and in the fall and winter of 1906-7. In the larger portion of these earlier cases there was more water in the soil, or about the trees, than in the less injured localities. More exposed situations also gave more injured trees. In 1906-7 the freezing was sudden upon unripened wood. (See Bulletin 192.)

Fig. 76. Peach tree, two years old, Carpenter, Ohio—one of those remaining alive though injured by freezing of 1906-7. Dead branches and ridge on trunk mark dead portion. From Bulletin 192.

Yellows. Peach yellows is a serious, contagious disease of this fruit in most portions of Ohio. Only in certain seasons may we find yellowish color as a marked symptom of affected trees. The true symptoms of yellows are: 1. Premature ripening of the fruit which is highly colored, often purplish spotted, and has the flesh marbled with red. 2. The premature growth of winter buds, resulting in excessive branching on new shoots, and the development of slender, wiry branched twigs. 3. Resting buds or adventitious buds are formed on the trunk and branches; these grow into sickly shoots with pale, narrowed leaves, and usually become much branched, with tips like veritable brooms. Aside from these specific evidences of yellows which serve to distinguish yellow color from true yellows disease, there are others less easily described but none the less useful to the practical observer. This disease may be recognized late in the

season by the late, adventitious growth. The sources of disease are diseased trees or affected nursery stock, more often the former. The remedy is to remove and to burn the yellows trees, root and branch, on the spot where found. Dragging diseased branches may spread yellows and all such trees are a menace. To leave an open hole over winter and replant the next year is a safe practice. (See Bulletins 72 and 92 for fuller discussion).

Fig. 77. Peach Yellows, winter buds of diseased tree unfolding in autumn. (After Smith, Farmers' Bul. 17, U. S. Dept. Agric.)

Recent investigations of this disease show that it is due to an enzyme which converts the leaf chloryphyll into a diseased form, causing yellows conditions. It is doubtless this enzyme which is transmitted, as in the case of tobacco, by actual contact. These discoveries have changed in no way our method of handling the disease. (See enzymatic diseases in introduction).

Rosette of peach is a disease of the southern states which appears to be similar in cause and transmission to peach yellows.

PEAR

Anthracnose. An anthracnose fungus (*Colletotrichum* sp.) occurs upon the fruit of the pear in the east, but has not been seen in Ohio.

Black-Rot (*Sphaeropsis malorum* Pk.) of the pear is the name applied to the rot like that of the quince and apple and due to the same organism. While it is less frequent as a source of fruit rot upon the pear, it is present both in this form and in the form of branch attacks or cankers.

Pear Blight or Fire Blight is one of the most serious drawbacks to pear growing. The symptoms of dead twigs and branches are well known. In substance our knowledge of pear blight is about this:—It is due to a bacterium (*Bacillus amylovorus* (Burr.) which, in the old cases of blight, winters over in the blighted parts. With April and May showers there is some exudation of watery substance from these parts, containing the zoogloa masses of the bacterium; when visited by insects these are by them transmitted to the opening blossoms. The microbe there breeds in the nectar of the blossom and in that manner attacks the branches; once within the tissues the microbe may spread indefinitely. Some varieties of pears are more susceptible, apparently, than others, which simply means that in them the microbes spread more rapidly. There is not a single variety of blight-free pear in our region. The remedy consists in cutting off and burning the blighted parts each autumn, extending the work to the crab-apple, apple and indeed to every variety of pome fruit which is attacked by this bacterium. In recent years Mr. Wm. Miller, of Ottawa County, has reported better results in blight control since he practices tnorough spraying of the trees in early spring with lime-sulfur. (Bulletin 79. Year-book U. S. Dept. of Agric. 1895).

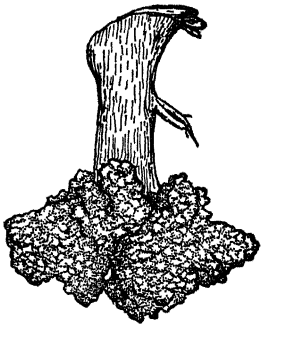


Fig. 78. Crown Gall on end of pear root.

Crown Gall. The crown gall attacks the pear both at the crown and upon tips of roots. It is less rapid in its destructive effects here than upon the peach, though but slightly less serious. Enlargements may be readily detected and they are usually of denser, woody growth than upon the peach. The same remedies apply here as with that fruit.

Leaf Blight of the pear is produced by the leaf blight fungus (*Entomosporium maculatum* Lev.) which causes spotting and dying of the leaves, also cracking of fruit. The diseased leaves show a dense, dark colored coating on the under side. This disease is readily and successfully prevented by the use of Bordeaux mixture as a spray.

Leaf-Spot of pear is another fungus disease which may flourish despite the use of Bordeaux mixture, as generally applied. This fungus (*Septoria piricola* Sacc.) appears not to yield to the standard fungicides. It produces small, circular dead spots in the leaves; the spots in later summer may drop out, leaving holes. It is quite prevalent, but as yet no specific recommendations can be made for it.

Pear Scab is a fungus disease allied to Apple Scab; the pear scab fungus (*Fusicladium pirinum* (Lib.)Fuckl.) being very similar in development to that of apple scab. This fungus was very abundant in 1898. It may cause spotting of the leaves or spotting of the fruit of the pear but is not readily distinguished from the other troubles save by the use of the microscope. It is prevented by the use of Bordeaux mixture.

Rust. The development of the early form of the cedar rust sometimes occurs upon pear as upon apple.

Sun-Scald is the name applied at times to the trunk injuries upon pear which are more commonly but the work of the pear blight bacterium at such points.

Sooty Disease. A sooty disease of pear fruit like that which occurs upon apple (see pages 372-3) likewise occurs upon the fruit and is also controlled by similar treatment.

PELARGONIUM

Dropsy. Some varieties of cultivated pelargonium, possibly called begonia, suffer seriously from dropsy. One bright scarlet flowered variety in particular has been cultivated at the Station. It often suffers from dead spots in the leaves. Before these spots in the leaves die, examination will show that there are wet looking places upon the under side of the leaf which appear translucent when held between the observer and the light. These are nothing more than leafcells which have become so gorged with water as to be ruptured. The break down extends to adjoining parts and then tends to produce the spots before described. This is purely a physiological trouble due to excess of water. The remedy is clear. Withhold water until absolutely necessary.

PEONY

Stem-Rot—Wilt. Frequent complaint comes to us of the dying of the stems of peony. The writer has had similar trouble. The disease has not been fully investigated. Massee and others have identified a rot fungus(*Botrytis* (*Sclerotinia*) *paeoniae* Oud.) to which more or less of the stem rot may possibily be referred. The symptoms are a gradual dying of the leaves. Examination shows stems to be rotted near the ground or often very much higher. A strong, insoluble fungicide might be successfully sprayed upon the stems without covering the leaves.

PEPPERS

Anthracnose. Two anthracnoses of peppers have been described from New Jersey, as occurring upon the leaves of the plants (*Gloeosporium piperatum* (E. & E.) (*Colletotrichum nigrum* (Ells. & Hals.) although the latter may at times be found upon fruits. In addition to these Dr. Halsted has demonstrated that cultures of the apple bitter-rot as well as the bean anthracnose, will flourish upon fruits of pepper.

PERSIMMON

Leaf Diseases. So far as known to the writer no strictly fruit diseases of the persimmon occur in our district. We may have at least three leaf diseases. These are an anthracnose fungus (*Gloeosporium diospyri* (E. & E.), the true leaf-spot fungus (*Cercospora atra* (E. & E.) and a powdery mildew (*Podosphaera oxyacanthae* (DC) De By.). The mildew will show like others, as a whitish covering upon the leaves, while the others are likely to inflict real injury to the leaf tissues. All should be possibly controlled by spraying.

PHLOX

Leaf-Spot. Cultivated phlox is frequently attacked by a leaf-spot fungus (*Septoria divaricatae* E. & E.). This mars the appearance of the leaves but is not often serious.

Powdery Mildew. There is a powdery mildew fungus also (*Erysiphe Cichoracearum* DC) sometimes found upon cultivated phlox. It develops as a whitish covering over the leaves and other parts. Both should yield to spraying properly done.

PINE

Damping-Off. A damping-off fungus (*Fusarium* sp.) has recently been very troublesome with seedlings of white pine in the east. This has been investigated and remedies have been tried successfully. These are either dilute sulfuric acid or powdered copper sulfate and lime; the former being sprayed on the seedlings about the base and the latter applied as dust. (See Cir. 4, Bur. Plant Indus.). It is likely that with efforts to grow white pine for timber purposes in this state, troubles of this type will not be restricted to this parasite.

Leaf Blight and Leaf-Spot. Leaf troubles have been met in most areas where white pine grows naturally or is being cultivated very largely. One of these so-called leaf blights is referred to a fungus, (*Septoria parasitica* Hartig). It has been found in adjoining states if not in Ohio. Another leaf-spot fungus (*Phoma strobi* Berk and Br.) is quite prevalent upon white pine in Eu pe. It is believed that this parasite or a closely related one, (*Phoma strobilinum* P. C.) occurs within our borders. Remedies have yet to be worked out for these troubles.

Root-Rots are to be expected in addition to the damping-off fungus before mentioned, especially among seedling pines under culture.

Rust. In Europe the blister rust fungus (*Cronartium ribicolum* Dietr. *Peridermium strobi* Kleb.) has been long known as a serious drawback to the culture of the white pine. Curiously enough this rust has until recently not been known in the United States. Not long since warning was sent out by the Department of Agriculture that this rust had appeared in America and should be sought for upon its alternate hosts, the white pine (Aecidia) and the currant and gooseberry. (Uredo- and Teleutospores). Upon the pine the aecidial stage develops numerous orange cluster cups infecting the stem toward the base. This causes high mortality among the young pines. Upon the currant and gooseberry the uredospores show yellow color which darkens as the teleutospores form. These are to be sought in August or early September, and by reason of the importance of this rust merit early attention by students of these diseases.

PLUM

Black-Knot. This is the same disease as that described under black-knot of cherry. It is more frequent upon the Damson than upon the other European plums, but requires only the removal and burning of the knots each year before March, in order to grow plums successfully and without serious injury from this disease.

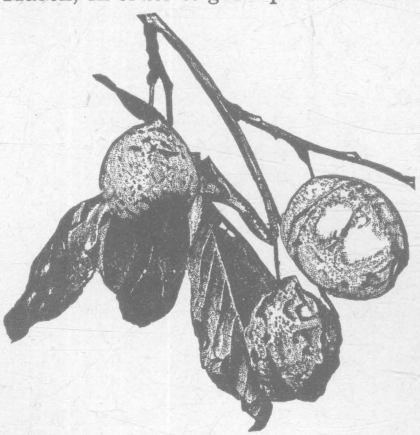


Fig. 79. Cluster of plums destroyed by rot causing "mummies." "Mummy" plums are dangerous whether left upon the tree or dropped to the ground, since they carry the rot fungus over the winter period.

Brown-Rot is by all odds the most serious disease with which Ohio plum growers have to deal, outranking by far black-knot, shot-hole fungus and all the other ills plums are heir to. It is the same in character as the rot of other stone fruits. As with the peach, the rot fungus (*Sclorotinia* (*Monilia*) *fructigena* (Pers.) lives over winter in the mummy rotted plums of the year before and possibly, to a limited extent, in affected branches. The first step in successful control of rot is the removal and burning of these old plums. The next step is to spray thoroughly, before the buds open, and to continue the spraying and picking the rotted plums as circumstances demand. Likewise,

control the curculio. For details of treatment see calendar. No halfway measures will yield satisfactory results in dealing with plum rot.

Cankers. In Europe trunks of the plum as well as trunks of forest trees suffer from canker caused by a distinct species of fungus. As yet we have no true proof of cankers due to these parasites in Ohio. The parasite is *Nectria ditissima.*

Crown Gall. This disease has been reported upon the plum as upon the peach, but is less frequent.

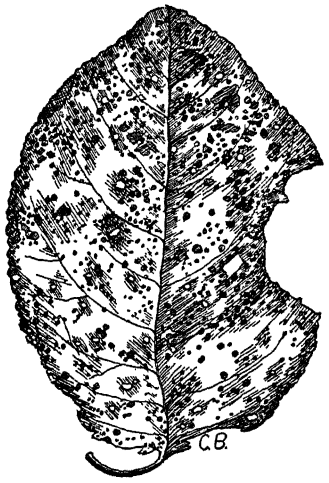


Fig. 80. Plum leaf attacked by Shot-hole Fungus This fungus is the same as that causing Leaf-Spot on cherry, but in this case the diseased areas of the leaf tend to drop out, leaving "shot-holes."

Leaf-curl. On Japanese varieties of plum, the leaves at times suffer from leaf-curl attacks similar to those upon peach. It should be reached by the same remedy, winter sprays.

Mildew. The powdery mildew fungus of the cherry (*Podosphaera oxyacanthae* (DC) De By) also occurs at times upon the plum, but is usually rather easy to control.

Pockets or Bladders. American varieties of plum are sometimes attacked by a fungus (*Exoascus* sp.) related to the leaf-curl fungus. This causes enlargement of the young fruits which are hollow; because of this condition they are sometimes alluded to as "bladders." The conditions which bring about the disease are the same as those of leaf-curl, viz., excessive cool wet weather in the early season. The winter spray as for leaf-curl should be effective.

Root-Rot. Plums are susceptible to attack of root-rot as in the case of other orchard fruits where set following timber or fruit trees that have suffered.

Shot-Hole Fungus is at times a very destructive disease of the plum. It is due to the same fungus (*Cylindrosporium Padi* Karst.) which attacks the cherry, although in this case even more serious injury is liable to result than with cherry trees. Where trees are defoliated by shot-hole fungus the fruit is of small value and the trees put forth new foliage and blossoms, thus leaving immature wood and a sappy condition for trouble in winter. Under such circumstances the secondary losses may be enormous. This fungus is readily prevented by spraying with standard Bordeaux mixture, the first application being made when the leaves are half grown, and two more at intervals of about three weeks.

Winter Injury or so-called Sun-Scald. In 1896-7, following neglected cases of shot-hole fungus which defoliated the trees in the fall of '96, some plum orchards were almost totally destroyed by the severe winter freezing. The sappy trees were not in condition to withstand the severe cold,— 15 degrees. Young trees were killed to the snow line while older trees had the sides of the trunk, commonly that facing to the southwest, severely injured. Plum trees were again injured by freezing in 1906-7. (See Bulletin 1[illegible]). The prevention of this trouble lies in the prevention of the shot-hole fungus and the avoidance of the conditions named. In some cases it is possible that protection of the trunk by straw or boards might be profitable.

Rust upon the plum has been collected in some of the western states, but at present has not been seen in Ohio by the writer

POPLAR

Anthracnose. Species of poplar or cottonwood are at times attacked by anthracnose (*Marsonia populi* Hals.). It produces similar effects to those of anthracnose upon sycamore.

Rust. The leaves of poplars are frequently attacked by the rust (*Melampsora populina* (Jacq.) Lev.) which disfigures the leaves by the spots caused through its development. The thrifty growth of poplars usually overcomes these foliage diseases under favorable conditions.

POTATO

Bacterial Blight. This is a serious disease of the potato; it also attacks the tomato, tobacco and egg-plant. It has been referred to a microbe (*Bacterium solanacearum* Smith). The parts of the stem attacked die off suddenly and the tubers from the affected plants have a dark discoloration of the tissues in a distinct ring at a slight distance from the exterior of the potato. Fungicides are practically useless for this disease. Such diseased tubers should not be planted nor should potatoes follow a diseased crop of tomatoes, egg-plants or potatoes. (Div. Veg. Path. B. No. 12, U. S. Dept. of Agric.)

Black-Leg. In much of Europe and in America the bases of potato stems are often attacked in the early season by a basal stem-rot which causes serious check to the growth of the plants. The diseased parts show well-marked lesions due to the work of a bacterium (*Bacillus phytophthorus* Appel.). Dr. Smith has recently investigated the disease in this country and has found it widely distributed. In Ohio it occurs to a certain extent and is at times quite similar in its effects to those referred to rosette. Measures of control will largely consist in rotation of the potato crop. See Bulletin Maine Expt. Station 174 (1909).

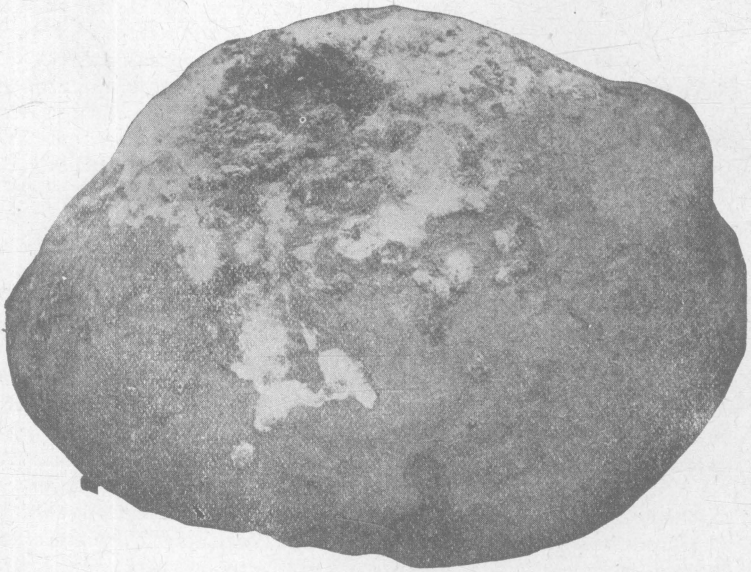


Fig. 81. A potato destroyed by Dry-Rot. This shows the characteristic appearance of the rotted potato.—From a photograph by T. F. Manns.

Dry-Rot. The dry-rot fungus (*Fusarium oxysporum* Schl.) has become generally prevalent in Ohio. This attacks the plant as the result of seed tuber or soil infection, causing wilt troubles of the plants (see Fusarium Blight) as well as dry-rotting of the tubers in storage. This tuber dry-rot is shown by the mold-like development of the fungus on the tubers. All such tubers should be rejected and rotation in potato growing should be practiced. Partly infected lots of potatoes held in storage should be promptly used. The infection of seed tubers is shown by cross sections near the stem end of the tuber at digging time or later. Where infection occurs there will be browning of the vessels near the exterior of the potato. In limited infection only small spots will show, but as the infection advances these brown tissues show as characteristic rings approaching that in bacterial blight. These spotted tissues yield the fusarium of infection in cultures as has recently been shown by the assistant botanist. Since we know that this parasite develops as a blight of the plant proper, we need to reject all diseased tubers for seed. (See Fusarium Blight).

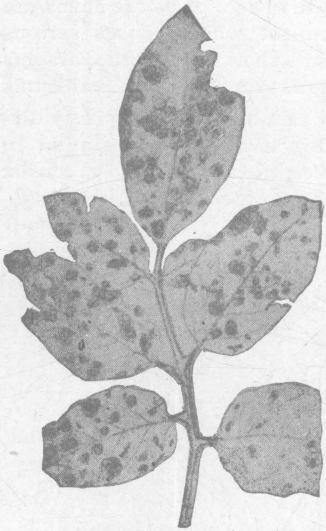


Fig. 82. Early Blight on potato leaf. (After Jones).

Early Blight of potato is a premature spotting and dying of the potato leaves, due to the work of a parasitic fungus (*Alternaria solani* (E. & M.) Jones & Grant). The occurrence of the early blight, however, is liable to be influenced by the general vigor and other conditions of the plant; yet there is no just basis for denying, in the light of our present knowledge, the parasitic nature of this disease. Jones has made cultures of the fungus and produced the disease by inoculation (Vt. Exp. Sta. Buls. 24 and 28; Rept. 1892) and has secured most admirable results by the use of fungicides. This successful spraying in itself is in the nature of proof of parasitic character. In the potato work at this Station it has been the uniform practice to spray thoroughly with Bordeaux mixture, adding arsenites for the insects, as required, and it has been many years since we have suffered any serious loss from early blight. However, the spraying for early blight will not prevent the bacterial disease above described, and it is doubtless the confusion of these two diseases that has led to such differences of opinion among potato growers as to the efficiency of spraying with Bordeaux mixture for early blight. There is real danger of the confusion of early blight with the Fusarium blight described in the following paragraph Our recommendation is still that contained in the spray calender, namely: to spray with Bordeaux mixture or some modified form of it.

Fusarium Blight. Early in the season of 1909 it was discovered that a small area of one of the unfertilized potato plots at the Station was dying out. Subsequently the area became larger and investigation showed the fungus to be that of dry-rot, which see. Later it developed that the yield of the entire tier of plots grown in three crop rotation, died prematurely although spraying had been practiced as usual. The dying plants showed infection and the dead areas had

in them black masses of a species of fungus (*Vermicularia*) whose relation to the disease is undetermined. At digging time it was found that in addition to grub injury, the tubers were very generally infected with the markings of the dry-rot fungus in the conducting tissues. Sections of the stem end showed brownish discolorations of the vessels, and occasionally tubers showed marked invasion by the fungus. Tubers collected elsewhere sometimes showed these discolorations of the vessels extending half the length of the tuber. Injury by grubs favored infection.

Following these discoveries quite thorough studies were made of potato conditions in the state, and it developed that the fusarium blight prevailed in local fields throughout the entire potato growing area. While some growers had obtained fine crops in spite of limited infection other growers had suffered seriously.

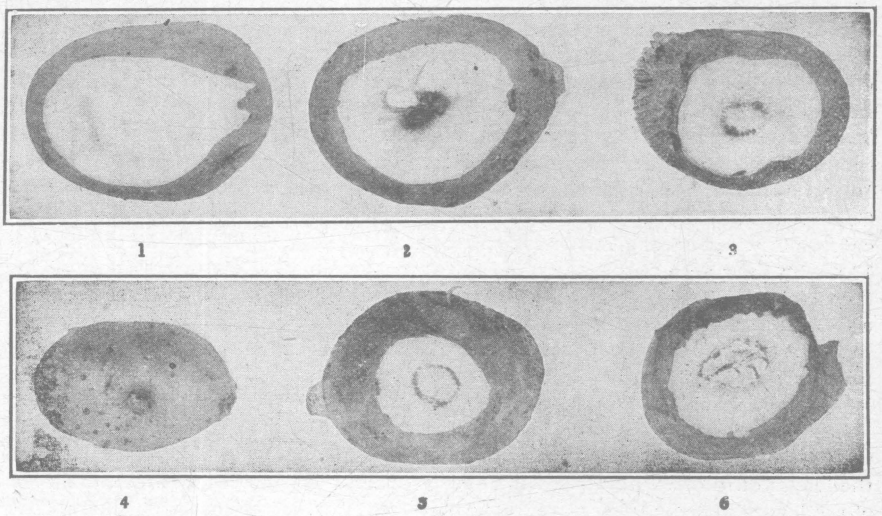


Fig. 83. Potato tubers attacked by Dry-Rot Fusarium, showing sections near the stem-end of healthy (No. 1) infected potato tubers. (Nos. 2-4) This infection may be easily discovered by cross sections made with a sharp knife, and sections from sterilized tubers give cultures in Petri dishes. At times the discolorations extend to the middle of the tuber.)From a photograph by T. F. Manns).

One grower in Summit county, who had succeeded very well in 1908 had such serious loss of crop from fusarium blight that he was led to attribute it to spray injury since blighting and dying went on in spite of the spray 'reatment. Investigation showed that his entire area was very badly infected with this fusarium. He was advised of the fact and warned against using infected seed or immediate planting of infected land. It developed also that northern grown seed showed up quite satisfactorily. On further examination it developed that the seed from Red River Valley and from parts of New York and possibly parts of Michigan was nearly free from infection by this fungus. It was also developed that seed potatoes stored in cellars have sometimes given much less satisfactory return than seed from the same field stored in outdoor pits. This would seem to be explained by the known fact that (*Fusarium oxysporum*) the dry-rot fungus, makes slow progress at low temperatures, that is 42° or below. This disease presents a real problem in potato growing for the year of 1910, and interpreting the results of 1908 in light of the experiences of 1909, one is led to infer that the disease then prevailed and accounted in part for the general early dying of potato tops.

In Europe, especially in Germany, in 1907 and possibly in the seasons since much complaint has been made of a similar disease to that described by Stewart as a leaf-roll disease (*Blattrollkrankheit*). In the European disease as well as in the stem blight of potatoes described by Stewart in New York (See Bulls. 101 and 138) and in our present fusarium blight, the leaves of the affected plants lose color and roll upward from the border. With this occurs a general loss of green in the plants. Orton, who has made a general study of the disease throughout the country, regards the fusarium of dry-rot as the causal organism, and finds very serious checks upon potato growing have resulted in San Joaquin county, California, upon so-called tule lands where continuous cropping in potatoes has been more or less practiced. The evidence is conclusive that we have in the dry-rot organism a blight organism of the potato plant which is at the same time a soil infesting as well as a seed tuber infecting fungus. In addition to this, incomplete observations support the idea that some spread of the organism takes place as with other fungus parasites in the field. In the matter of preventive measures and remedies, the first consideration should be given to seed tubers. These should be of such source and character as are clear from infection. This infection may easily be determined by cutting across the stem end of the tubers. Evidently cellar stored seed is dangerous during this period of epidemic. In the matter of spray prevention we have evidence in a cooperative test in Portage County, that the spray holds back the advance of the development. Upon duplicate plots where strong Bordeaux mixture was used, the gain was at the rate of 13 bushels per acre above any other sprayed plots; and 9 bushels per acre above the checks. These plots remained green longer than any of the others and show a decided reaction to the copper fungicide. From the behavior of certain hills in the various fields whose tops remained green in spite of the general infection, breeding for blight resistance should give decisive results.

Late Blight or Rot of the Potato (*Phytophthora infestans* De By) called in Europe "the potato disease" is caused by a downy mildew fungus. This mildew spots the leaves, producing a downy, felt-like covering in spots on the under side of the leaves of infested plants. This causes prompt dying with wet-rot conditions of the leaves and the tubers are rapidly destroyed with wet-rot appearances. The potato Phytophthora is a disease which like its host plant is accustomed to somewhat cooler conditions of climate than usually prevail in Ohio. However, in the years 1904 to 1907 all the summer months were several degrees below the normal; this resulted in continuous out-breaks of the blight or rot, culminating in 1906-7. In 1908 under warmer or drier conditions while the fungus was found at Wooster it did not inflict damage here or elsewhere in the state. It is unlikely to be injurious in Ohio, except in seasons cooler and more moist than normal. (See table of seasons page 354).

Spraying for late blight is entirely successful and should begin by the 20th of July, being repeated at intervals of two weeks and applications made at the rate of 100 gallons per acre on full grown vines. The duration of the spraying will depend upon the maturity of the plants, in the late crops reaching four or occasionally five sprayings.

Rosette. The Rosette or Rhizoctonia disease often prevails in Ohio, especially where potatoes are grown on acid soils. This acid condition is evidently favorable to the fungus which attacks the stems of the young plants or even in early developments of the stems, these are often rotted off below the surface for the earth. In later developments the elongation of the plant axis is stopped and a rosette appearance is shown in the leaves. The disease survives by the red-

Fig. 84. Showing a plant of potato affected with Rosette. The elongated injury below the soil surface shows as dark-colored in the figure.—From Bulletin 139.

Tip-burn. Potato leaves often show dead margins or tips even where no parasitic attack can be discovered. Such "tip-burn" effects may also be increased by any extra weather stress as of drouth or by spray injury. These conditions are to be met by avoiding the causes which bring them about.

Wart-Disease. This disease, also called "canker" and "black-scab" is caused by a soil infesting fungus, (*Chrysophlyctis endobiotica* Schilb) and has recently become established in New Foundland and possibly at other points in North brown sclerotia upon the seed tubers; these are largely controlled by seed treatment with formaldehyde or corrosive sublimate. (See bulletins 139 and 145).

Potato Scab is a well known parasitic disease of the potato tuber that needs no extended description. Whether due to fungi or bacteria, or both, the practical prevention of potato scab consists in destroying the parasites on the seed potatoes and then in planting them in soil free from those organisms. The organisms in question will usually be found in soil on which potatoes were grown the previous year, or in that freshly manured. The materials used by this Station in treating for scab are two, namely, solution of corrosive sublimate and solution of formalin, as per strengths given in spray calendar. It is ineffective to treat the seed and then plant on scab-infested land. See also Wart-disease.

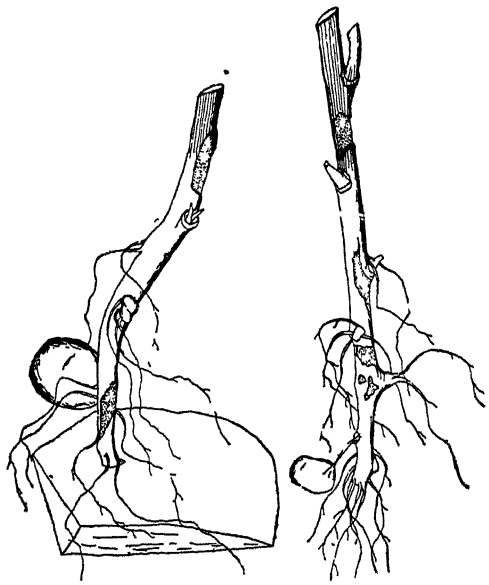


Fig. 85 Bases of potato stems showing lesions caused by Rosette Fungus. The shaded areas were dark with an abundance of the fungus, and the tops showed conspicuous Rosette effects. From Bulletin 139.

America. It was discovered upon potatoes from upper Hungary in 1896 and has since become distributed over much of northern Europe including Germany, England, Ireland, Scotland and Wales. Apparently this wart disease is the most serious potato trouble yet met with in cultivation, since it causes large warts upon potatoes but partially infected and converts those badly attacked into corky masses not unlike lumps of coke. Such tubers are entirely unfit for human food though they may be used for stock food after cooking. The fungus causing the disease survives in the potato by resting spores as well as by its vegetative parts and appears to remain as a soil infestation for five to six years. Seed treatment is not effective in controlling the disease. Every effort should be made to secure the exclusion of the disease from the United States and to recognize it should imported tubers carry the trouble. See Güssow, Bulletin 63 Central Experimental Farms (Ottawa) and Orton, Circular 52, Bureau Plant Industry 1910.

PRIMULA

Rot. A rot of Chinese primula due to Botrytis and similar to that on peony has been reported and may be expected with us.

PRIVET

Anthracnose. Privet in hedges is frequently attacked by anthracnose (*Gloeosporium cingulatum* Atk.). This shows itself by lesions in the younger stems and results in dying of the portions of the attacked branches beyond the lesions. This weakens the hedge and sometimes results in secondary consequences. While spraying has not been fully worked out for this disease, it should prove an effective remedy at the proper time.

PUMPKIN

Downy Mildew and Wilt attack pumpkins after the manner described under muskmelon and cucumber. The remedies are the same as there stated.

QUINCE

Anthracnose. The fruits and possibly the branches of quince are attacked by an anthracnose fungus (*Glomerella rufomaculans* Sp. & V. Schr.) which is the same as that causing bitter-rot in apple. According to our knowledge of the survival of this fungus, attention must be given to gathering and burning of "mummy" fruits and to the cankers produced, if any, upon the branches. The spraying treatment necessary is the same as that for apple bitter-rot.

Black-Rot. The fruit and foliage of the quince are attacked by black-rot. The black-rot multiplies very rapidly in the fruit of quince and often causes loss of much or that produced. This fungus (*Sphaeropsis malorum* Pk.) also develops as a leaf-spot upon the foliage causing defoliation. It is liable to attack the branches after the manner determined for apple. To hold this fungus in check very careful spraying is required at times, but as a rule it is easier to keep down the black-rot on fruit and foliage of quince than to keep it down on susceptible apples. The spray used is Bordeaux mixture.

Leaf-Spot of another kind which is identical with that upon pear is found at times formed upon the quince. It is controlled by the same treatment as the black-rot.

Blight. The blight upon quince (*Bacillus amylovorus* (Burr.) De Toni.) is slightly less destructive than that upon pear. It is caused by the same bacterium and requires the same watchful care and attention as in the case of pear.

Pale-Rot. This (*Phoma cydoniae* Sacc.) is reported from some of our states and may occur in Ohio. There is no evidence to indicate that it will require more prolonged treatment than black-rot or leaf-spot.

Rust (*Gymnosporangium* sp.) also occurs upon the quince when trees are near cedars which carry the cedar apples and distribute spores. Labor must be devoted to the destruction of the source of infection as in the apple.

RADISH

Black-Rot, Club-Root. Black-rot (*Bacterium campestre* (Pamm) and club-root (*Plasmodiophora brassicae* Wor.) occur upon the radish at times and are of the same nature and cause as these diseases upon other mustards, especially cabbage and cauliflower. The attention to control will be similar to that for cabbage.

Downy Mildew and White Mold (*Peronospora parasitica* De By. and *Cystopus candidus* Pers.) also occur upon the leaves of radish, the latter more especially upon younger plants. These are the same diseases that have been described upon other mustard growths.

RAPE

Black-Rot, Club-Root, etc. Rape, as other mustards, is attacked by a group of diseases which are common upon plants of the mustard family. These are black-rot, club root, white mold, etc., that are more fully described under cabbage, cauliflower and radish.

RASPBERRY

Anthracnose (*Colletotrichum venetum* (Speg.) Hals.). The anthracnose fungus is a frequent bane to the raspberry grower. It attacks the young canes and so spots and injures them, as well as the foliage, that when the time arrives for ripening the fruit the plants are unable to do this and the crop is largely lost. The Horticulturist of this Station has always succeeded in holding this disease in check by use of the methods of spraying recommended in the calendar for anthracnose. Care, however, must be used in the application of the spray to reach the stems of the young canes and to keep the fungicide from the leaves of bearing canes where it will do injury.

Fig. 86. Raspberry stem attacked by Anthracnose. This causes "birds-eye" spots of the stems. After Scribner.

Cane Blight. Serious dying of raspberry canes has occured in some of the northern districts where they are largely grown. These troubles range from "dieback" to impaired vigor in which there are seeming brown patches upon the stems. As a rule these have failed to yield a specific organism and may be the result of root conditions which appear to be quite unsatisfactory on both raspberry and blackberry, as described under the former.

Crown Gall is at present one of the most destructive diseases attacking raspberries. In some well marked cases upon the variety known as Thompson's Prolific (Bulletin 79) eel-worms have been suggested as the possible cause of the gall production;

but whatever the cause of the galls attacking that variety we have found them transmitted to the peach in the same soil and we have found that practically all of the varieties of raspberries are attacked by a similar trouble producing like excrescences. These galls result in the destruction of the bearing canes, and where the raspberries are planted in orchards the disease, it would seem, may extend to the orchard trees as well. Late investigations show that a bacterium is the cause of crown gall on the almond. (Science N. S. Vol. XXIII, No. 575, pp. 424, 425; by Erwin F. Smith, U. S. Dept. of Agric.). Prompt removal and burning of all affected canes is the only method of treatment. Indeed it has been demonstrated from the very beginning that a healthy raspberry plantation cannot be secured by the selection of apparently healthy plants from diseased areas. Nothing remains but to secure plants from healthy plantations.

Fig. 87. Crown-Gall on raspberry plants. These also occur on the roots.

Bacterial Blight of raspberries has been described by this Station; it has not recently proved serious. (Bulletin 78).

Leaf-Spot and Rust. The leaf-spot fungus, already described for blackberries and dewberries, upon which it is more commonly found, was prevalent in 1899 upon raspberries. The only remedy for rust (*Caeoma nitens* Schw.) is the removal and destruction of all clumps either wholly or partially infected. The leaf-spot fungus (*Septoria rubi* West.) will yield to spraying with Bordeaux mixture. Winter injury usually occurs and is shown by the killing back of canes which fail to mature properly. The remedy must lie in the avoidance of the conditions.

RED-TOP

Anthracnose (*Colletotrichum cereale* Manns.) was found upon red-top, as also upon timothy, orchard-grass, wheat, rye, oats and chess. The symptoms are the same as for the other grains; the disease attacks the culms and sheaths upon the lower part of the stem. The chief interest which comes from the disease upon grasses is the means this may serve to carry the disease of one rotation to the next in cereals.

ROSE

Anthracnose. An anthracnose fungus (*Gloeosporium rosae* (Hals.) attacks the rose, causing defoliation of the canes; indeed the whole plant is attacked. This behaves very similarly to the anthracnose fungus of the raspberry. Young plants are found most susceptible to the disease. The methods of handling are practically the same as for the anthracnose of the raspberry.

Crown Gall. Crown gall trouble essentially the same in character as that of raspberry, occurs on roses but requires no separate description here.

Leaf Blotch (*Actinonema Rosae* (Lib.) Fr.) often causes dark spotting of the leaves. The frost-like, branching growth over the leaf-surface is often very pretty in design though injurious in effect. If the rosehouse is too moist, or if other conditions be slightly unfavorable, the fungus seems to flourish all the better. It may be checked by the use of Bordeaux mixture or by dilute copper sulfate solution, as recommended for cucumbers in the greenhouse (One pound to fifty gallons).

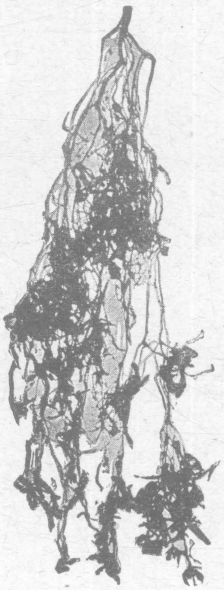


Fig. 88. Branch of rose root with Nematode Galls.

Rose Mildew is attributed to the fungus (*Sphaerotheca pannosa* Lev.) which is commonly prevalent in rosehouses; it is also found occasionally out of doors. This mildew is, for the forcing house, largely diagnostic, indicating, when prevalent, uneven temperatures. Proper attention to the matter of heat is the best preventive. Sulfur is often sprinkled upon plants and is frequently used upon the steam pipes, but it is not clear that the influence is very great.

Nematodes. Among the most serious of the rose diseases is that caused by the eelworms or nematodes which attack the roots. As with cucumbers, these parasitic worms induce the growth of small bead-like galls upon the roots of the rose. The leaves dry up from the margins, the plants generally turning yellow and breaking down as the outcome of this interference with the proper work of the roots. This subject of nematodes is discussed at length in Bulletin 73. No successful remedy has been found for plants once attacked. The method of prevention consists, as in the case of cucumbers already cited, in the proper steaming and treatment of the soil designed for use in the rose benches.

Rust (*Phragmidium subcorticium* Schrank.). This is occassionally met and proves very disfiguring. As yet we can advise nothing more than the choice of rust resistant sorts.

RUTABAGA

Rutabaga is attacked by the same diseases as attack turnips.

RYE

Rye Anthracnose. This new disease was very serious upon rye in 1908 and was surely prevalent in 1907. The spores are carried by adhering to the seed grain and can be discovered in centrifuge separations of grain washings. In rye fields the anthracnose attacks both the heads and the lower portions of the culms. The localized attack upon the head (rachis) kills all that portion of the spike above the point of attack and the grain is but partly developed. See Fig. 90. Upon the bases of the stems, including the roots, the fungus develops its dark masses often closely packed together and dotting both stem and sheaths (see figure). In 1908 the loss of yields in rye were from 25 to 60 percent of the total crop.

Fig. 89. Head and upper portion of stem or rye attacked by anthracnose, The point of attack upon the head is shown by the removal of the glumes; that portion above died. Upon the stem the dark spots are the acervuli of the anthracnose. From Bulletin 203.

For control of the disease thorough separation of all the light rye kernels in the seed and subsequent seed treatment are recommended. (See Bulletin 203).

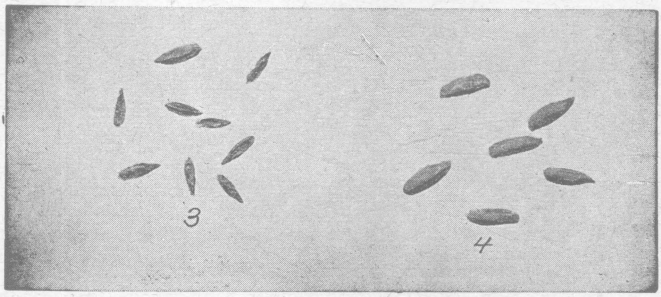


Fig. 90. On the left kernels of rye shriveled from an attack of anthracnose; on the right, normal, healthy kernels of rye. From Bulletin 203.

Ergot occurs occasionally in rye; the fungus (*Claviceps purpurea* (Fr.) Tul.) attacks the kernel and transforms it into a large club-shaped dark mass, the ergot of the druggist. The amount of ergot is usually not enough to be a serious trouble in our state. Ergotism in domestic animals is sometimes caused when diseased rye is fed to them.

Rust. The species of rust which occur upon wheat are also found upon rye. (See wheat).

Scab. The scab (*Fusarium roseum* Lk.) as is shown by recent work at this Station attacks rye almost as freely as wheat. The fungus in question is shown by recent work to be the same as that in wheat. The remedy is the same as that recommended for anthracnose.

Smut. The fungus (*Urocystis occulta* Wallr.) of stem and blade smut in rye occurred at this Station in 1909. It attacks the culms, leaves and leaf-sheaths but not commonly the floral parts. The smutted parts swell and burst open in elongated lines. Seed treatment may reduce this smut but hardly prevent it altogether.

SALSIFY

White Rust (*Albugo tragopogonis* Tul.) attacks this plant and is sometimes destructive. The best results seem to be promised by avoiding sources of infection and by spray treatment.

SORGHUM

Bacterial Blight of sorghum is somewhat similar in its general appearance to the bacterial blight of corn already described, and is caused by a specific organism (*Bacillus sorghi* Burr.). It has been described in the Kansas Experiment Station Report for 1888.

Grain Smut (*Cyntractia Sorghi-vulgaris* (Tul.) Clinton) attacks the seed of the sorghum plant. The hot water treatment may be adapted to prevent this.

Head Smut (*Sphacelotheca reiliana* (Kuhn) Clint.) occurs occasionally where sorghum is grown, but is less common than grain smut.

SOYBEAN

Wilt occurs in most districts where soybeans are grown. We have had very few reports in Ohio. Indications show that the one most likely to occur is that due to a wilt fungus (Fusarium).

SPINACH

Anthracnose occurs upon spinach but is not definitely known in our district.

Downy Mildew. The downy mildew fungus (*Peronospora effusa* (Lev.) Rabh.) is already known upon lamb's quarters and may appear upon the cultivated spinach of the same order. It shows as discolored or dead spots in the leaves with felted, downy covering underneath. Methods of prevention here would be as for cucumbers, except that applications could scarcely be made after the plants are nearly developed.

In older trucking districts other diseases such as white smut and scab have been reported, but are not known to occur with us in Ohio.

SNAP-DRAGON

Anthracnose. Stewart has described an anthracnose fungus of snap dragon (*Colletotrichum antirrhini* Stew.). This attacks the leaves causing brown spots and is at times serious. It may be successfully combatted by spraying with Bordeaux mixture.

Stem-Rot. A stem-rot (*Phoma* sp.) also attacks the stems of snap-dragon at any point above the ground. It is especially severe on the younger or sucker stems.

SQUASH

The squash is attacked by diseases already described under cucumber, namely, anthracnose, downy mildew and the wilts. The remedies are likewise the same.

SOLOMON'S SEAL

Leaf Diseases. Solomon's Seal is attacked by a fungus (*Aecidium convallariae* Schul.) which causes characteristic orange-colored cluster cups, and by a leaf-spot fungus (*Phyllosticta cruenta* (Kickx.). This latter disease is liable to give increasing trouble in culture.

Smut. Parts of this plant are also attacked by a smut fungus (*Urocystis colchici* (Schl.) Rabh.). I believe this is rather infrequent.

SPRUCE

Leaf-Spot. Norway spruce in Ohio has suffered seriously in 1908-9 from attacks by a leaf-spot fungus (*Phoma* sp.). This fungus causes the discoloration of the leaves (needles) also their dropping. The fruit bodies of the fungus occur upon the scales of the branches as well as upon the leaves and are evidently capable of surviving from year to year. This leaf-spot or leaf blight has been reported from several counties upon hedge plantings, upon large shade trees and upon sizes grown for Christmas trees. Drouth conditions in 1907 were a large factor in this matter causing the death of many spruce trees in 1907 and 1908. It is believed that winter and early summer sprayings will have some effect in checking the leaf trouble. This experience shows the need for mulches about Norway spruce, especially in the southern portion of Ohio.

Seedling diseases are liable to prove troublesome thus checking efforts to grow seedlings of spruce.

STRAWBERRY

Aborted Fruits. In certain seasons, and especially in 1908, there were many reports of misshapen and aborted fruits. In certain cases the salable fruit was less than 50 percent of the whole. These misshapen fruits are rarely the result of disease, more often they are the indirect result of imperfect pollination. The effects of weather conditions in hindering pollination and making it imperfect are well known. Some bright sunny weather is all essential.

Anthracnose (*Gloeosporium fragariae* Mont.) has been found upon strawberry leaves in other states; it has given less trouble than the other foliage diseases with us up to this time.

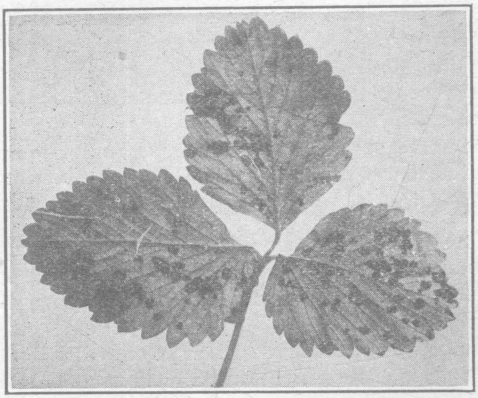


Fig. 91 Leaves of strawberry attacked by Leaf-Spot. The lighter centers have dark borders. This fungus forms ascospores in the strawberry leaves. From a photograph by T. F. Manns.

Leaf-Spot or Rust so-called is the most serious disease of older strawberry leaves. The leaf-spot fungus (*Sphaerella fragaria* (Tul.) Sacc.) matures in the old leaves. In the earlier spots on young leaves three forms of fungi are found, most of which are probably stages in the development of the leaf-spot fungus. This disease is essentially one of the season before the crop is injured. Spraying upon new plantations after picking any fruit present will usually be found profitable. The practice of burning over strawberry beds after picking to destroy old leaves and the fungi upon them, as well as possible insects, is based upon right principles and is commonly successful.

SUGAR BEET

Crown-Rot (*Phoma betae* Frank) has been discovered in most of the sugar beet growing states and is liable to be present in Ohio in the factory district.

Leaf-Spot. The sugar beet, which is beginning to be extensively cultivated with us, has been injured by the leaf-spot fungus (*Cercospora beticola* Sacc.) and by other diseases. The leaf-spot produces small, dead areas in the beet leaves, followed at times by dying of all the leaves. For this fungus Bordeaux mixture may be applied with confidence, at intervals of three weeks. The first application should be made when the plants are about 5 or 6 inches high.

Root-Rot occurs at times, particularly upon beet seedlings where planted in rich mucking soil. The fungus

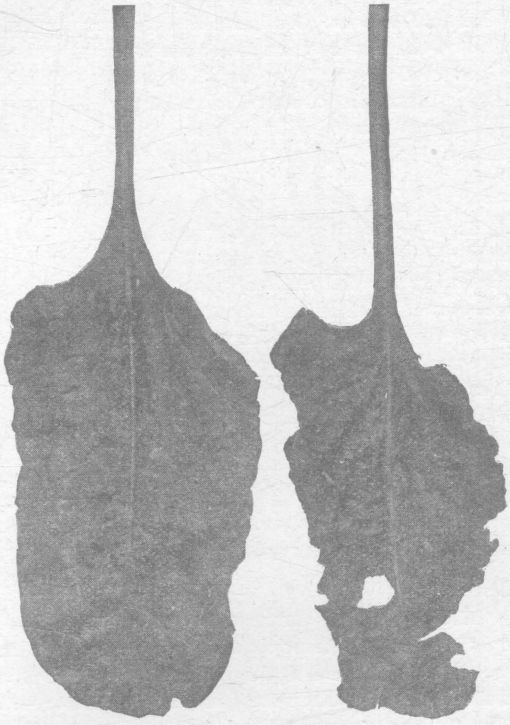


Fig. 92. Leaf-Spot trouble on sugar beet.

appears to be the same as that attacking the greenhouse seedlings of lettuce tomatoes, etc., (*Rhizoctonia* sp.) and can apparently be reached only by similar methods.

Beet Scab affects the roots of the beet as the scab does potato tubers. It is thought to be due to the same organisms. It may be avoided largely by avoiding the conditions for scab already mentioned under potato scab. Rotation of sugar beets will probably be required to escape this and other diseases.

SWEET POTATO

Bin or Soft-Rot is encountered by the sweet potato growers. The fungus (*Rhizopus nigricans* Ehrh.) producing it may be present in the plant bed and apparent as dark spots or rotted tips on the plants at setting. All such plants ought to be discarded if avoidance of disease is sought. Some experiments were made at Marietta in 1897, to prevent or reduce this rot, but without positive advantage in the keeping qualities. A dope or mixture of 6 parts earth to one part flowers of sulfur was dropped in handfuls and the plants set through the mixture thus bringing it about the roots of the plants very nicely. Smoother potatoes were obtained and these separated more readily from adherent earth, but no better keeping qualities resulted for that year. The potatoes were harvested, however, during a wet period and conditions were less favorable than is often the case.

Soil-Rot (*Acrocystis Batatas* Ell. & Hals.) is a serious disease of sweet potatoes for which the above described treatment has proved successful in New Jersey. (N. J. Exp. Sta. B. 126).

Stem-Rot (*Nectria Ipomoeae* Hals.) attacking the stems and roots has appeared in Ohio sweet potato fields, apparently introduced by affected seed. Such seed should be avoided. Rotation may also be necessary.

White Mold or White Rot (*Cystopus Ipomoea-panduranae* (Schw.) Farl.) is common upon the Man-of-the-earth and the wild morning glory (*Convolvulus hederaceae*) in the sweet potato districts, but apparently is not frequent upon sweet potato foliage.

Black-Rot. This disease of sweet potato roots shows in dark, somewhat greenish spots of varying diameter. It causes serious losses in the roots and from diseased potatoes gives "black shank" in great abundance upon the young plants. The fungus (*Ceratocystis fimbriata* Ell. & Hals.) has been described as a result of Dr. Halsted's work in New Jersey. In treatment the measures are largely preventive in the choice of healthy seed, healthy sprouts and the sterilization of the plant beds.

SWEET CORN

Bacterial Disease has at times proved serious in sweet corn fields, but is apparently the same in character as that attacking sorghum, broom corn and field corn.

Smut (*Ustilago Zeae* Beckm.) also attacks sweet corn and where crops are grown consecutively in garden, the amount is sometimes excessive. The cause of it is the same as that of field corn and the conditions of control are the same.

SYCAMORE

Anthracnose (*Gloeosporium nervisequum* (Fckl.) Sacc.) is periodically very destructive on the foliage of the sycamore, extending at times to the younger shoots. The warm wet springs appear to be favorable to it; such was noticeably the case in 1908 and again in 1909. The outbreak in these years extended all over eastern United States. While the disease should be amenable to fungicides, it has been neglected.

Powdery Mildew. The leaves of the oriental sycamore, which is planted largely in Cleveland and other cities, are much disfigured by the powdery mildew fungus (*Microsphaera alni* (?). This was studied by the writer in Cleveland in 1909. It was found that younger trees were subject to attack by the mildew fungus late in the season, so that a foot or more of the tip of the shoot was disfigured by the mildew and many of the leaves were prevented from full development. The fungus does not complete its development early, and up to November 15th no spore sacs were formed. This leaves moderate doubt as to the exact identity of the fungus. It is hoped to hold this mildew in check by spraying which seems to be necessary on younger trees of the oriental sycamore.

TIMOTHY

Anthracnose (*Colletotrichum cereale* Manns)occurs upon timothy and as already noted on blue-grass, orchard-grass, red-top, wheat, rye, etc. The attacks so far studied, are confined to the culms and sheaths upon the lower part of the stems showing small dark masses of the anthracnose fungus as spots upon them. This shows that the timothy is liable to carry over the disease between the wheat crops.

Bacterial Blight of Head. See blue-grass.

Rust (*Puccinia poculiformis* (Jacq.) W) Some seasons this is very prevalent upon timothy resulting in much spotting and premature drying up of the foliage. This was true to a notable degree in Ohio in 1908.

Smut (*Tilletia striiformis* (Westd.) Wint.) attacks the blades of timothy and produces interesting developments in them. As a rule the amount of smut is not serious. (See smut of blue-grass).

TOBACCO

Bacterial Blight. The same bacterium that attacks potato, egg-plant, etc., at times attacks tobacco plants, especially in the early development. (See wilt).

Bed-Rot. Tobacco plants are often destroyed by damping-off fungi; at times even the root-rot fungus may be present in the beds. Owing to the need to use beds several years in succession for plant growing the same fungus which gives us trouble in greenhouses is very liable to give us trouble here. In the old world some of the common damping-off fungi are reported. With us our particular bed-rot troubles are due to Rhizoctonia. For checking this disease it seems desirable to treat the tobacco beds in late fall with formalin drench at the rate of 2 1-2 to 3 pounds of formalin to 50 gallons of water; this to be applied to beds at the rate of one gallon per square foot after spading up thoroughly and incorporating all fresh manure before the treatment is applied. The beds should also be fairly moist. After this treatment no stable manure should be applied, although mineral fertilizers can be used. If the treatments are delayed till spring it will be impossible to sow sooner than two weeks following this drench. (See Circular 59, 1906).

Fig. 93. Tobacco plants showing bed-rot, Rhizoctonia.

Broom-Rape. In certain infested districts in Brown county the common broom-rape (*Orobanche Ludoviciana* Nutt.) attacks the roots of tobacco, while in Kentucky the hemp broom-rape (*O. ramosa*) also occurs even to a greater extent than in Ohio. Nothing can be done to prevent these attacks of this parasite which produces its own flowers and seeds after once established. If losses are large it would be wise to rotate crops on infested land to get rid of the broom-rape.

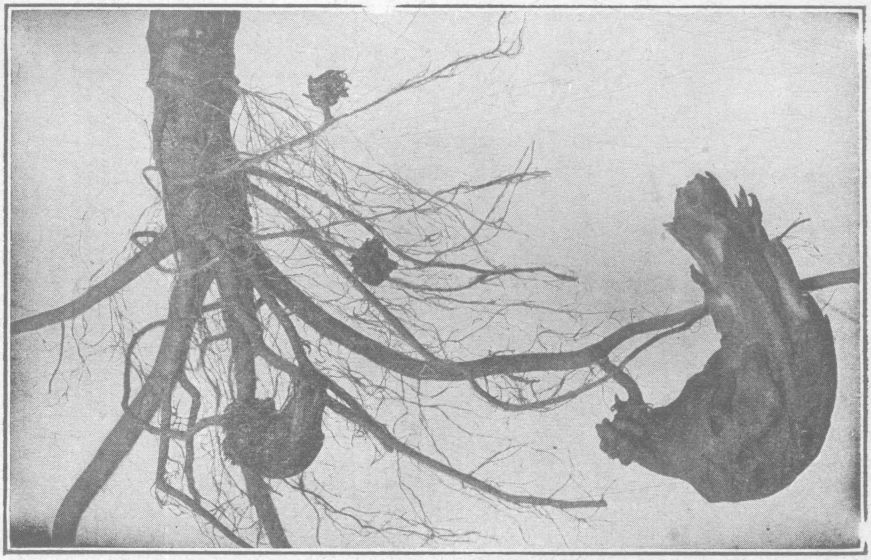


Fig. 94. Roots of white burley tobacco plant attacked by broom-rape. Each of these masses attached to the root shows beginning of the plant which will grow up in larger dense form, and produce an abundance of blossoms and seeds but no leaves. Each one of these must have started from a buried seed of the broom-rape, *Orobanche Ludoviciana* Nutt.

Curing House Troubles. At times tobacco growers have in very moist weather troubles from rotting in the curing house. These are called shed-burn, pole-burn, etc., and are difficult to control under unfavorable weather conditions. Thorough ventilation of the houses is certainly necessary where these are feared.

Downy and Powdery Mildew (*Peronospora sordida* B. & B.) and (*Erysiphe communis* Wallr.) both occur in the old world, but up to this time have not been listed in America.

Leaf-Spot (*Cercospora nicotianae* E. & E.) (*Phyllosticta nicotiana* E. & E.) occurs in some tobacco states, but is very rare with us.

Mosaic Disease also among the enzymatic diseases, is not very common upon tobacco, except in seasons when the normal development of the plants is interfered with by excessive rains and water logged soils. In Connecticut the disease is known as "calico," diseased plants showing a mottled appearance due to the alternating areas of dark green and yellowish green in them; they are

veritable mosiacs. As shown a few years since by Beijerinck, Wood and others, these diseases and others of their class show a yellowing of foliage due to oxidizing enzymes in the leaves. Further as shown in experiments made in 1904, (see Bulletin 156) at Germantown, this disease is communicated from one plant to another by touching. The experiment included touching a succession of plants after touching a diseased plant; these touchings were sometimes repeated. During the period of one month there was an increase of 67 percent in those touched following contact with diseased plants. This shows the advantage of handling mosaic plants at separate times from healthy ones.

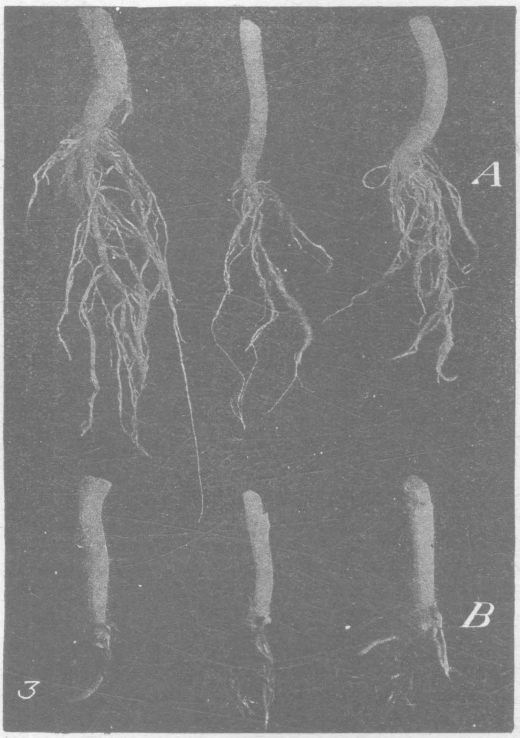


Fig. 95. Roots of seedling tobacco plants from soil inoculated with *Thielavia basicola:* A. Soil sterilized with formalin (1 to 200) and B. untreated. After Gilbert Bulletin 158, Bur. Plant Ind., U. S. D. A.

Root-Rot. Root-rot (*Thielavia basicola* Zopf.) on tobacco was first discovered by the writer upon plants received from Clermont county in 1899; since this time it has been more or less serious during wet seasons. In the vicinity of

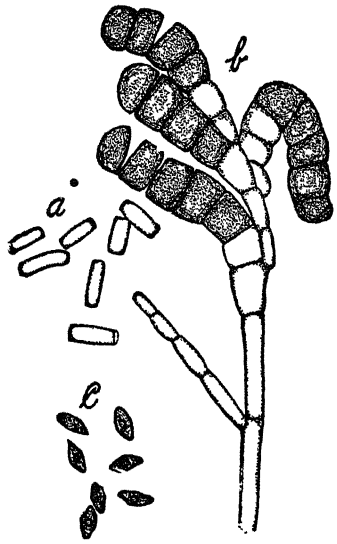


Fig. 96. The fungus of tobacco root-rot (*Thielavia basicola* Zopf.). Camera lucidia drawing or the fungus as it occurs upon ginseng, tobacco and begonia. *a* and *b*, conidial forms; *c*, ascospores. All magnified 565 diameters. From a drawing by J. M. VanHook.

Hartford, Conn., notably at Litchfield, this disease has been troublesome on certain soils; the same fungus has been found upon catalpa seedlings in Ohio. It is better known as attacking the roots of violets. In all cases there is a blackening and rotting of the roots of seedling plants where they are attacked. Thorough steaming of the bed soil should be practiced where this trouble comes in, to avoid transplanting it to the field. In the field as has recently been pointed out by Gilbert and Briggs, the check on growth of tobacco is much greater in wet seasons than in dry ones. Apparently attention must be given to the drainage of the land which becomes infected if this is to be continued in tobacco.

Wilt (*Bacterium solanacearum* Erw. Smith) has occurred frequently in North Carolina and has more recently been sent to the writer from shade plantations in Florida where considerable acreage was lost in 1908, due to infection through the soil. This bacterial disease has recently been investigated by Stevens and others, but it is not believed any methods of treatment will evade the necessity for rotation. (See Bulletin 156 also potato wilt.)

White Speck has been studied in North Carolina and attributed toa specific fungus (*Macrosporum Tobacinum* E. & E.) Another fungus of the same genus has been accredited in the same state as the cause of brown-rot, but these have not been studied in Ohio.

TOMATO

Anthracnose (*Colletotrichum phomoides* (Sacc.) Chest.) occurs occasionally upon tomato fruits, causing small depressed spots in them. The same fungus may at times attack other parts of the plant. This disease seems to be checked by the use of Bordeaux mixture. (See also Collar disease).

Bacterial Blight of the tomato, egg-plant and potato has already been mentioned. It was destructive at Mt. Carmel, near Cincinnati, in 1896 (B. 73). It has since been locally destructive. It causes sudden blighting and decaying of the stems and branches attacked. Spraying has as yet proved useless for the blight. Preventive measures recommended, include fighting insects, early removal of diseased vines, choice of fresh land not previously in potatoes or egg-plants, and tomato seed from healthy sources. To date this disease has been less destructive than the leaf-spot.

Collar Disease *Vermicularia* sp. Recently a peculiar collar disease of fall greenhouse tomatoes has come under study. In this case the symptoms were abnormal leaf development, after the manner of mosaic disease by artificial inoculation. The collar trouble was quite noticeable.

The case under study occurred in houses that appeared to be over-watered. The plants set very little fruit and were not profitable. The root system appeared to be normally developed except the adventitious whorl of roots near the surface. Between these upper roots and the root crown below, the collar of the plant

is surrounded by a development of what appears to be a parasitic fungus, a species of Vermicularia. The black masses of the fungus are also visible extending down upon the root bases which are lighter in color. A similar abundance of Vermicularia has been noted on the dead stems of potato tops which have died from fusarium blight.

This collar disease is just now under study. We believe something can be accomplished by spraying with Bordeaux mixture about the base of the plants. Certainly good will come by withholding excess water. This case of disease was described where fusarium blight and mosaic disease also prevailed. The fern-like leaf development is ascribed to the presence of the mosaic disease. The association of the two diseases may be casual.

Leaf Mold (*Cladosporium* (?) *fulvum* Cooke) is a common trouble in tomato forcing-houses in the fall or near the close of the season. It produces spots in the leaves, while beneath they are covered by the grayish-brown mold fungus. The fungicides heretofore recommended for use in the greenhouse are available for the tomato leaf mold.

Leaf-Spot or Leaf-Blight is an outdoor trouble, as is anthracnose. The leaf-spot fungus (*Septoria Lycopersici* Speg.) appears to be gradually traveling westward from the Atlantic coast, where it first appeared several years ago. During 1898 it was locally disastrous over the whole of Ohio, and again during 1900 and 1909. It may be successfully prevented by about three thorough sprayings with Bordeaux mixture, though some difficulty attaches to the treatment of unstaked tomato plants in the field. (Bulletins 73, 89, 105).

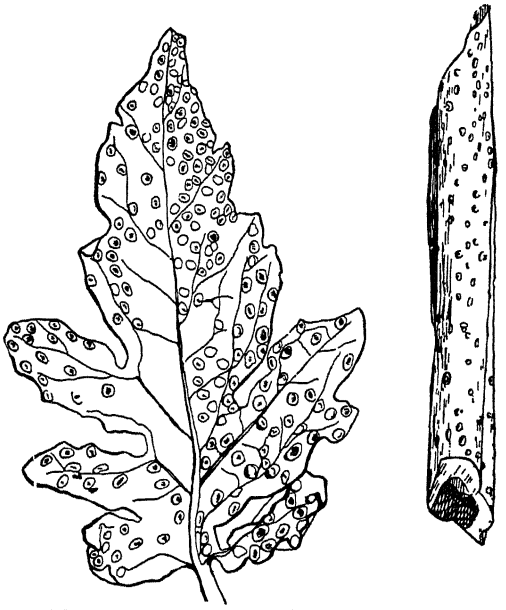


Fig. 97. Tomato leaflet and stem attacked by leaf-spot. This causes dying of the leaves in showery seasons

Mosaic disease attacks the tomato under conditions similar to those giving trouble to cucumbers, tobacco, etc. It is believed we have a mosaic disease analogous to that in tobacco and that the remedy is pointed out by the fact that the disease may be transmitted by touching first diseased and then healthy plants.

The symptoms of the ordinary type of the disease are the alternation of darker green and yellowish-green color in the leaves; this makes the plants conspicuous under ordinary circumstances. In 1909 with cases under glass, where the collar disease appeared to be associated, abnormal leaf forms were observed without very apparent intermixing of yellow areas in the leaves. The actual leaf forms suggested the name of fern-leaf trouble. In these specimens the internodes of the plants, the stems of the compound leaves and the petioles of the leaflets were all elongated; the leaf-blades were narrowed at times to mere borders along the mid-ribs. Gradations were also found between these extreme

forms and the normal leaves. Recent investigations by Westerdijk show the disease to be distinct from the mosaic disease of tobacco though doubtless analogous; the modified leaf forms were obtained by artificial inoculations both by Westerdijk and in the Pathologium of this Station by Manns.

Nematodes may be very injurious to tomatoes grown under glass. They cause, as on cucumber plants attacked, gall-like enlargements on the small roots of the tomato. Previous soil treatment to destroy the nematodes is the remedy in this instance, as in the other. It will usually occur that tomato plants are less susceptible to injury by nematodes than are cucumbers and melons.

Point Rot of green tomatoes, especially in the forcing-house, is often the most serious trouble with which the tomato grower under glass has to contend. It was stated in Bulletin 73 that this trouble was observed to be most destructive in cases of scant water supply in the soil. This observation was again confirmed by the Horticultural Department of the Station during the season of 1899. The trouble was checked by abundant and careful watering, even when it had been very bad, and was again produced by withholding water and allowing the plants to dry out. The cause appears to be largely due to conditions of drouth, and while other causes than the one just stated, notably a certain bacterium does join to produce point rot, none other appears so under control as water conditions. The remedy lies of course, in the avoidance of drouth from which the rot may indirectly result.

Root-Rot or Rosette occurs frequently in greenhouses where tomatoes are grown following crops of lettuce. The fungus produces various effects which are commonly damping off of the younger seedlings or collapse of the older ones; recently a basal constriction of the stem of mature plants is traced to Rhizoctonia. In this case wilting of plants resulted. It seems to be propagated under greenhouse conditions where much organic matter is used and calls for soil disinfection through steaming or formalin drench as described elsewhere under lettuce and under soil diseases. In older plants the symptoms are shortened development of the axis giving effects similar to that in lettuce.

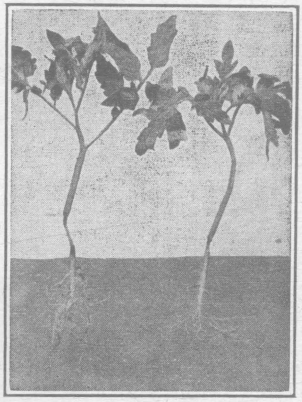


Fig. 98. Stems of young greenhouse tomato plants damped off from attacks of "Rhizoctonia." From a photograph by T. F. Manns.

Sclerotium Blight. This is a wilt disease first reported by Rolfs from Florida but it is now present in Ohio greenhouses. The first symptom is wilting of terminal portion of plant. The dead plants and diseased portions shows in them sclerotia of the fungus which causes the trouble. These are of the size of mustard seed or smaller, at first milk white and finally mahogony red to black. Sometimes these sclerotia grow together in anvil-shaped masses. Burning diseased plants is advised.

Wilt. A wilt (*Fusarium* sp) of tomatoes in addition to that described under bacterial disease has been discovered recently in greenhouses in Ohio as well as other states. It is due to a Fusarium.

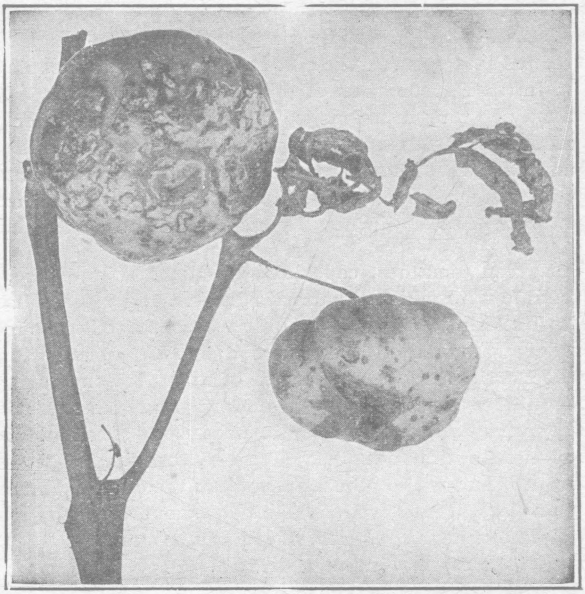


Fig. 99, Tomato fruits with browned and diseased spots in them. This form of disease results from Fusarium Wilt of the plants; also probably from Bacterial Wilt. From a photograph by T. F. Manns.

The symptoms of this wilt are rather characteristic. It may attack plants either vigorous or of slow development. Commonly the first symptom noticed is the yellowing and drying up of the lower leaves. Soon dark areas appear in the stem and also in the fruits. At all stages cross sections show darkening of vessels. The roots become darkened and watery in the region of the vessels. Eventually the top of the plant wilts and the leaves die both above and below, while the fruit has become worthless. We believe this to be a soil infesting disease that should be controlled by thorough soil sterilization.

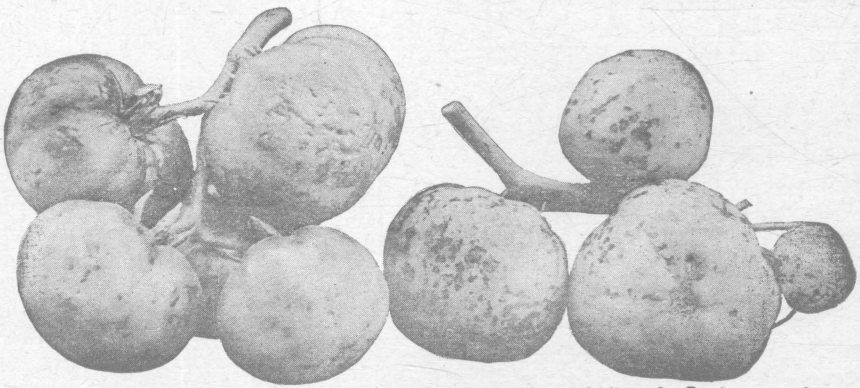


Fig. 100. Similar fruits of green tomatoes spotted by effects of blight in Station greenhouses in 1895. From Bulletin No. 73.

TURNIP

Black-Rot. The same bacterium attacks turnips as cabbage, cauliflower and other mustards; the diseased roots show blackening of the parts with final decay.

Club-Root. This fungus organism (*Plasmodiophora Brassicae* Wor.) infests the roots of many cultivated mustard plants, including the turnip, radish, rutabaga, etc. The treatment is the same as stated under cabbage.

Downy Mildew (*Peronospora parasitica* (Pers.) De By.) sometimes occurs attacking turnip plants.

VERBENA

Mildew. Cultivated verbenas are attacked by the mildew *Erysiphe Cichoracearum* D C) which is so common on the wild vervains. It is to be treated as other powdery mildews, by spraying with fungicides.

VERONICA

Leaf Diseases. Cultivated species of veronica are attacked by several leaf diseases, which have been imperfectly studied. Perhaps the most common of these is due to the typical leaf-spot fungus (*Septoria veronicae* (Rob). There are other parasitic species which attack the genus, including a downy mildew and a rust.

VETCH

Spot. A spot disease (*Protocoronospora nigricans* Atk. and Edg.) has been described as new from New York.

The Wilt of Vetch similar to that of soy beans, cow peas and cotton has also been described.

VINCA

Leaf-Spot. The large flowered vinca is occasionally disfigured by a leaf-spot (*Sphaeropsis vincae* Sacc.) which may also develop as a stem disease. It has not been studied carefully with us.

VIOLET

Leaf-Spot and **Leaf Blight** (*Phyllosticta Violae* Desm. and *Cercospora Violae* Sacc.) are sometimes prevalent, and with downy mildew of violet should yield to spraying with fungicides.

Nematodes of violets are, on the other hand, not amenable to spray treatment. The parasite in the case is the same as named under cucumber nematodes, likewise its effects. Soil treatment will also be effective in prevention here.

Root-Rot. Root-rot (*Thielavia basicola* Zopf.) has not been reported as troublesome by greenhousemen in Ohio, but it is scarcely possible it can be entirely lacking when the disease occurs upon tobacco and catalpa in fields. The blackening and rotting of the roots, due to the fungus, will impair the development of the plants and the flower growth seriously. It does not seem possible that anything short of sterilizing the soil and starting new plants will ckeck the root-rot where once established.

VIRGINIA CREEPER

Leaf-Spot. The leaves of virginia creeper are frequently curiously spotted by a leaf-spot fungus (*Phyllosticta labruscae* Thüm.) which gives dying spots with colored border. This leaf-spot is also very common upon the Japan creeper and is identical, according to recent reports, with the leaf-spot of the grape; indeed we have a large number of the well known diseases of the grape attacking the Virginia creeper. These include anthracnose, which may be distinct, the black-rot fungus, of which this Phyllosticta may be a stage and possibly others. This would be especially true in the vicinity of cultivated grape vines.

WALNUT

Anthracnose or Leaf-Blight. The leaves of walnut, as well as the leaves of butternut, are attacked by an anthracnose fungus (*Marsonia juglandis* Sacc.) which in common with other anthracnoses, is capable of serious injury to the leaves of these trees. It is believed that this fungus will be held in check by sprays.

Leaf-Spot. The walnut is also attacked by other leaf fungi producing leaf spots, but these have not been investigated by us in Ohio.

Mildew. The same powdery mildew which attacks a variety of trees (*Mycrosphaera alni* DC.) also attacks the leaves of walnut, growing over and forming a mildew covering.

WATERMELON

With the possible exception of the wilt disease and the leaf-spots, the diseases of the watermelon are the same as those which attack cucumbers and muskmelons. They include anthracnose, downy mildew and leaf blight. The leaf-spot of the watermelon is referred to a distinct fungus (*Cercospora citrullina* Cke.) though its ravages are, possibly, not general. (See Bulletins 73, 89, 105). In the treatment of watermelon vines it is advisable to use the more dilute Bordeaux mixture, Bordeaux II, of the calendar.

WHEAT

Anthracnose (*Colletotrichum cereale* Manns). In 1907 centrifuge examinations were made by the Assistant Botanist showing the presence of anthracnose spores in the washings of shriveled wheat samples. The disease was discovered in the fields generally over Ohio in 1908 and has recently been described in Bulletin 203. This anthracnose is certainly the cause of shriveling in wheat. It appears to be the obscure trouble sought for some years by the writer. In common with other anthracnoses it develops as maturity approaches and on wheat it attacks the lower portions of the stems and sheaths resulting in apparent whitening of the spikes with decided shriveling of the grain. The fungus may be detected by the color changes in the field and by the dark spots appearing on the sheaths and stems where attacked. It is believed that thorough separation of shriveled grain by recleaning seed wheat and treatment of seed wheat with formaldehyde drench will be favorable to keeping down the amount of anthracnose. It is admitted that the presence of the fungus upon grasses and

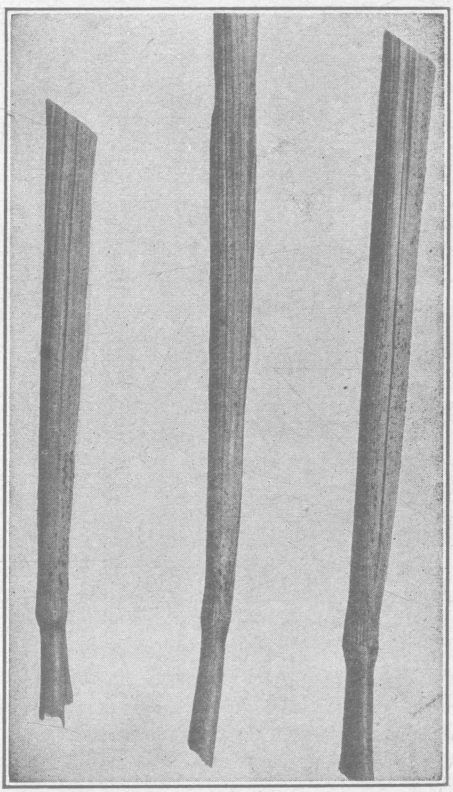


Fig. 101. Culms of wheat with both stems and sheaths attacked by anthracnose. The dark spots are caused by the fungus. From Bulletin 203.

upon other cereals increases the danger of its being carried over in rotation. (See rye, oats, timothy, also Bulletin 203.)

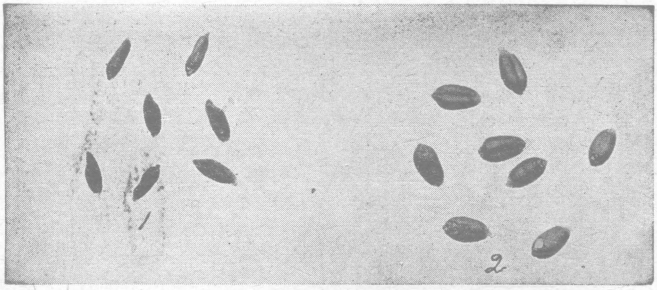


Fig. 102. This shows on the left, wheat shriveled by anthracnose attacks of the plants; on the right normal healthy kernels of wheat of the same variety. From Bulletin 203.

Blade-Spot or Leaf-Spotting has occurred upon wheat in considerable extent in Station plots during the last year or two. Small areas were killed by the fungus and this leads to somewhat premature dying of the leaves This leaf disease calls for further investigations.

Grain Diseases. It must be remembered that anthracnose and scab are both in a sense grain troubles. They cause shriveling and loss of quality in the grain. In addition a fungus (*Alteraria* [illegible].) causing dark spots in wheat kernels has been found by this department. Scab must also be included here since the parasite attacks the wheat kernels.

Powdery Mildew. This whitish fungus (*Erysiphe graminis* DC.) also appears upon leaves of wheat plants. Usually it is of small importance in Ohio but of much interest.

It attacks wheat both in pot cultures under glass and in outdoor growth. In both cultures the conidial development of the fungus is very troublesome invading the older leaves and causing premature death. In the field the consequences are usually not studied, but the perithecia of the fungus are often found upon straw blades and other parts that have been invaded. It is clear that the fungus cannot be beneficial to the development of the grain in attacked plants.

Scab. The scab disease (*Fusarium roseum* Lk) has been again investigated and the results published in Bulletin No. 203. It has been found that the same scab fungus attacks also rye, emmer, oats and spelt, producing the various effects upon these grains. On all attacked heads in wheat the portion diseased shows reddish or pink covering with the fungus and the part of the spike above this is killed. Of course, all kernels contained in that part are much shriveled and are commonly invaded by the scab fungus. In addition a recent study showed that many various sized kernels of wheat are infested with this fungus internally, although still capable of starting to grow and making a new plant. Investigations made in

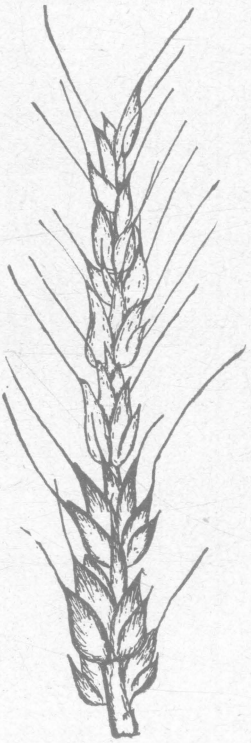


Fig. 103. Wheat spike attacked by scab. The upper portion of the head is shrunken and has been killed by the pink fungus.

culture dishes and greenhouse recently, show that the fungus survives in the old dead seeds as well as in some capable of germination and attacks the seedling wheat plants during the first month of their growth. In the continuous wheat plots of the Station it was found that nearly 6 percent of the plants were killed off in the unfertilized plots during 1907; the fertilized plots show a good deal less and the rotation plots a great deal less (see Bulletin 203). Not only may the fungus survive in its perithecial form upon wheat heads, straw and dead scab grains, but it may survive in grain capable af germination as well as in the soil. See pages 334-335. Recent studies of diseases of clover and alfalfa seem to show that this same fungus is the cause of serious clover and alfalfa sickness. It would thus appear to be carried over through rotations of clover, etc. The best method of handling appears to be recleaning seed wheat and getting out all shriveled kernels which are often scab-infested as well as all under sized kernels thus evading a large share of the infection in seed wheat.

Seedling Blight. The seedlings of wheat are killed off by the attacks of the scab fungus which is transmitted in the seed as well as in the soil devoted to continuous wheat culture. (See scab above, also Bulletin 203.)

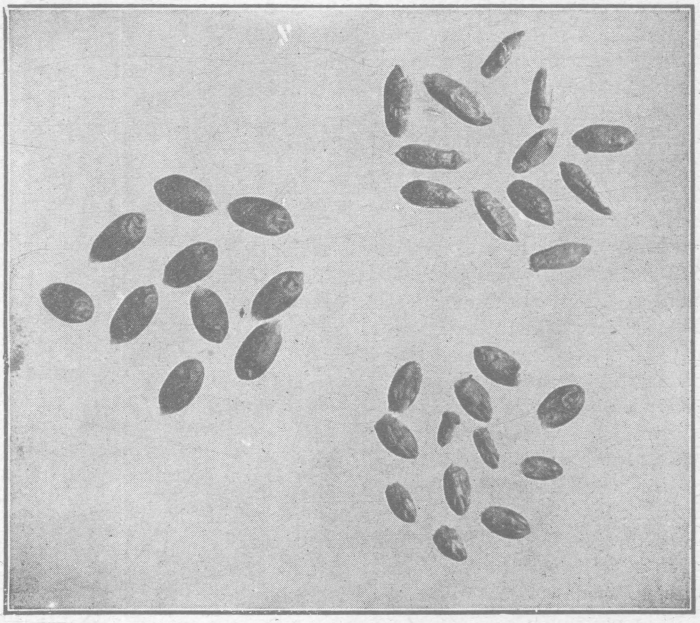


Fig. 104. On left, healthy normal kernels of wheat; on the right, above kernels injured by scab which will not germinate—below kernels injured by weavil. From Bulletin 203.

Loose Smut. This is a smut fungus (*Ustilago Tritici* Jensen) which converts grain and glumes into a sooty mass of spores. These heads of loose smut are most obvious at the blossoming of the wheat. The disease is worse on certain varieties of wheat. It may be prevented by the modified hot water treatment as per calendar.

Rust. While essentially the same to the ordinary observer, the wheat rust is produced by two rust fungi (*Puccinia graminis* Pers. & P. *rubigo-vera* D C). Only the last named passes the winter in the wheat plant. Both have the light red and the black (dark) stages and are very damaging under conditions which favor the rust. In Europe, Australia, and California wheat growers hope to select rust proof varieties of wheat. Recently in England quite an impetus has been given to wheat breeding by the work of Biffen upon resistant varieties of wheat. This resistance applies in the English studies not only to rust, but to some other features. The matter of resistance is the hope of rust prevention. (See Bulletin 97.)

Fig. 105. Heavy spike of bearded wheat destroyed by loose smut. These smut spores are scattered and find entrance into the forming kernels of wheat when the blooms open for pollination.

Stinking Smut of wheat is caused by a still more destructive smut fungus, (*Tilletia foetens* B & C) which converts the kernels of wheat into dirty, stinking masses of spores. These, if abundant, ruin the flour and render the wheat valueless for human food. At times 40 percent of the wheat is thus destroyed and the losses from it are often very large. Recent investigations have established that this smut is caused by the smut spores sown with the seed grain. If the smutty seed wheat is treated with a fungicide, such as bluestone, hot water, formalin, etc., which will destroy these spores without injury to the grain and the treated seed is then prevented from subsequent infection, dried and sown, a clean crop may be grown from smutted seed. For details of treatment see calendar and Bulletin 97, which treats of the diseases of wheat.

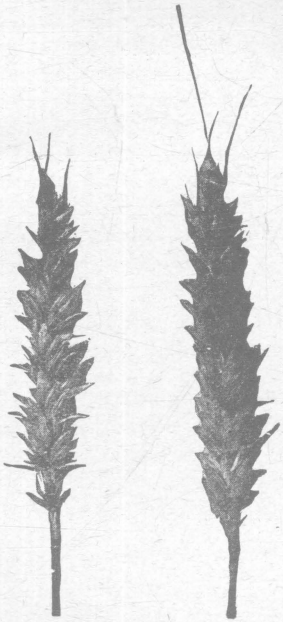


Fig. 106. Diseased and sound spike of Poole wheat. In the one at the left the kernels have been destroyed by Stinking smut and spikelets are spread abruptly.

WHITE PINE

See Pine.

ADDENDUM

Corn, Root-Rot, (*Fusarium* sp.). Recently the Department has made preliminary studies of a root-rot of corn attributed to a species of Fusarium of similar behavior to the scab of wheat, potato fusarium and cabbage wilt, in that the parasite appears to survive in the affected soil, as well as elsewhere. From Fayette county comes the report of diseased corn roots in patches where the stalks blow over easily, and rarely form mature ears. Roots of such plants are partly killed and thus weakened. At present we can only advise rotation of crops. More knowledge is needed with all this type of soil infesting diseases.

Raspberry, Cane Blight (New York). In reference to cane blight conditions, page 437, this specific disease described by Stewart (Bul. 226, N. Y. Agric. Expt. Sta., 1902) was not mentioned. Stewart identified the disease on specimens sent to him from Ohio in 1902. Recently other specimens have been received from Cuyahoga and Wood counties. The earlier reference to cane blight forms indicates how serious the raspberry condition is in Ohio. The parasite causing the disease is *Coniothyrium Fuckelii* Sacc. The fungus attacks the plants killing and discoloring the bark and wood, thereby causing wilting of bearing canes, and the ultimate death of the parts that have been attacked. The foliage on affected canes wilts suddenly and becomes dry. The whole cane may be involved, or only a part of it. At times a single branch is killed, while the remaining cane continues apparently normal. It is feared that this disease is very common in our unprofitable raspberry plantations in Ohio. The disease is doubtless disseminated in plants from diseased plantations, and by the ordinary agencies of wind, rain, etc. Naturally the dissemination by these last two agencies is local. Preventive measures will include healthy plants, planting on new uninfected land and a prompt cutting out and burning of old canes after fruit is gathered. Stewart's work indicates inconclusive results from spraying.

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